historic structure report
historical data section
september 1983

UPPER DELAWARE
THE DELAWARE AQUEDUCT

NATIONAL SCENIC AND RECREATIONAL RIVER / NEW YORK-PENNSYLVANIA

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HISTORIC STRUCTURE REPORT
HISTORICAL DATA SECTION
THE DELAWARE AQUEDUCT
UPPER DELAWARE NATIONAL SCENIC AND RECREATIONAL RIVER
NEW YORK - PENNSYLVANIA

By

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NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR
DENVER, COLORADO

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PREFACE

This historic structure report (historical data section) has been prepared to satisfy in part the research needs as stated in the task directive (approved by Mid-Atlantic Acting Regional Director Don H. Castleberry in a memorandum dated February 3, 1983) concerning the Delaware Aqueduct under Package No. 337. Data from this report will provide an information base which will be used to plan the restoration/preservation and interpretation of the structure. The emphasis of the report has been focused on the significance of the bridge's (and John A. Roebling's) contributions to the evolution of suspension bridge technology, architectural modifications and maintenance/repair efforts during the period while the aqueduct served as a component of the Delaware and Hudson Canal, and the post-1898 architectural evolution of the structure relative to its conversion as a private toll bridge.

A number of persons have assisted in the preparation of this report. Special thanks are due to Superintendent John T. Hutzky, Chief Park Ranger Ronald A. Wilson, and Interpretive Specialist Calvin Hite, of Upper Delaware National Scenic and Recreational River, for sharing their ideas on the nature of research required for the project, making available to me the park files for reference purposes, conducting me on a guided tour of the structure, and providing me with the names of local people to interview. George Hartman and Mary Curtis of the park staff also provided useful information on the location of local residents to interview. John W. Bond, Associate Regional Director, Planning and Resource Preservation, Mid-Atlantic Regional Office, and two members of his staff, Clifford Tobias, Regional Historian, and Sandra Hauptman, Park Planner, also provided useful suggestions and available documentation from their files for the report. Ronald W. Johnson, Chief, Cultural Resources Research, also made helpful suggestions and provided useful documentation for the report. My thanks also go to Evelyn Steinman, editorial assistant, for typing the manuscript.

Harlan D. Unrau

June 1, 1983

STATEMENT OF HISTORICAL SIGNIFICANCE

The Delaware Aqueduct, built in 1847-49 to carry the Delaware and Hudson Canal over the Delaware River between Lackawaxen, Pennsylvania, and Minisink Ford, New York, is the earliest extant suspension bridge of John A. Roebling, one of the leading 19th century American civil engineers who is best remembered for his crowning work--the Brooklyn Bridge--built to his design by his son Washington. The aqueduct is the third work of Roebling's, and in all likelihood, it is both the oldest suspension bridge in the United States and perhaps the oldest extant cable suspension bridge in the world that retains its original principal elements. Thus, the structure is one of the nation's most significant engineering treasures. The sole survivor and largest of four wire cable suspension aqueducts erected by Roebling for the Delaware and Hudson Canal between 1847 and 1850, the Delaware Aqueduct stands today only because of its strategic location. Following the abandonment of the canal in 1898, the structure was converted to a private highway toll bridge.

The national significance of the Delaware Aqueduct has been recognized both for its historical and engineering importance. Along with four other components of the Delaware and Hudson Canal, the Delaware Aqueduct was designated as a National Historic Landmark in 1968 and was thus included on the National Register of Historic Places. In 1972 the American Society of Civil Engineers designated the structure a National Historic Civil Engineeering Landmark.

CHAPTER ONE

BRIEF HISTORY OF THE DELAWARE AND HUDSON CANAL TO 1850

The Delaware Aqueduct was built as a part of the almost continuous program of general improvements to increase the carrying capacity of the Delaware and Hudson Canal in the 1840s. Thus, it is important that a brief historical overview of this waterway and its periodic enlargements be examined to place the structure in its historical context.[1]

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1. Data for this section is based on a summarization of information in the basic works on the history of the Delaware and Hudson Canal. These works include: Edwin D. LeRoy, _The Delaware and Hudson Canal and It's Gravity Railroads_ (Honesdale, 1980); Manville B. Wakefield, _Coal Boats to Tidewater: The Story of the Delaware & Hudson Canal_ (South Fallsburg, New York, 1965); Dorothy Hurlbut Sanderson, _The Delaware & Hudson Canalway: Carrying Coals to Rondout_, 2d ed. (Ellenville, New York, 1974); _A Century of Progress: History of the Delaware and Hudson Company, 1823-1923_ (Albany, 1925); and Malcolm A. Booth, "The Delaware and Hudson Canal With Special Emphasis on Deerpark, New York" (unpublished M. A. thesis, State University of New York, College at Oneonta, 1965).

In addition a number of other works contain chapters or significant references relative to the history of the Delaware and Hudson Canal. These works include: Alvin F. Harlow, _Old Towpaths: The Story of the American Canal Era_ (New York, 1926), pp. 185-94; Noble E. Whitford, _History of the Canal System of the State of New York_, 2 vols. (Albany, 1906), I, 728-51; Jim Shaughnessy, _Delaware & Hudson: The History of An Important Railroad Whose Antecedent Was a Canal Network to Transport Coal_ (Berkeley, 1967), pp. 1-23, 37, 60; Robert M. Vogel, _Roebling's Delaware & Hudson Canal Aqueducts_ (Washington, 1971), pp. 1-36; Frederick Moore Binder, _Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860_ (Harrisburg, 1974), pp. 16-19, 46-51, 92-99, 112-13, 138-39, 144-49; The Hudson Coal Company, _The Story of Anthracite_ (New York, 1932), pp. 59-72, 85-92; and W. J. Coughtry, "Construction of the Delaware and Hudson Canal," _The Delaware and Hudson Railroad Bulletin_, X (July 15, 1930), 219-20; (August 1, 1930), 229-30, 238; (August 15, 1930), 245-46, 252; and (September 1, 1930), 267-68.

Also see U. S. Department of the Interior, National Park Service, The National Survey of Historic Sites and Buildings, Special Report, Delaware and Hudson Canal, Pennsylvania and New York, by John D. McDermott, August 5, 1968, and "Engineering in the Early Days of the Delaware & Hudson," _Engineering News - Record_, XC (May 10, 1923), 840-41.

The canal was projected by Maurice and William Wurts, dry goods merchants from Philadelphia, as a means of exploiting their considerable anthracite coal holdings near Carbondale in northeastern Pennsylvania which they had acquired over a period of years beginning around 1814. At first the Wurts brothers mined small quantities of the coal and transported it to Philadelphia by wagon, barge, and raft, but the returns were marginal. The poor financial profits were a result of high transportation costs, the somewhat undependable means of these modes of transport, and competition from the Schuylkill and Lehigh coal fields that were located closer to the city and had the advantage of navigation over greatly improved rivers.[2]

The Wurts brothers determined to make New York City their target market area as it was potentially the nearest profitable urban area for their product and would undoubtedly require increasing amounts of anthracite to meet its heating, lighting, and power demands in the years ahead. Thus, in the early 1820s the brothers set out to find a feasible means of transport for their coal and thus determined that a canal linking the Delaware and Hudson river valleys was the most practical way of reaching that city. At the time the Erie Canal was arousing all America to enthusiasm for canals. This "canal fever," along with the quickening pulse of economic and industrial expansion then taking place in the United States in the aftermath of the War of 1812, made it likely that they would find both political and financial backing for their proposed venture.[3]

The Wurts brothers organized the Lackawaxen Coal Mine and Navigation Company in 1823 to operate their mines and transport their product. They obtained authorization from the Pennsylvania state legislature on March 13, 1823, to canalize and improve nativation along

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2. Whitford, History of Canal System of New York, I, 728-30; Harlow, Old Towpaths, pp. 185-86; and Shaughnessy, Delaware & Hudson, pp. 1-2.

3. Shaughnessy, Delaware & Hudson, pp. 1-2, and LeRoy, Delaware & Hudson Canal, pp. 3-8.

the Lackawaxen River and to construct a waterway along the river if necessary. In April a group of financiers and capitalists from New York City and Sullivan and Orange counties in New York formed the Delaware and Hudson Canal Company. On the 23rd of that month the New York state legislature authorized the incorporation of the canal company with a capitalization of $500,000 to construct a canal of "suitable dimensions" and "with necessary appurtenances" from the Delaware River through Orange, Sullivan, and Ulster counties to the Hudson River.[4]

Benjamin Wright, then the principal engineer directing construction of the Erie Canal, was hired to make a detailed "survey or running level carried over the country from tide-water of the Hudson river, at the mouth of the Walkill, up the valley of the Rondout, and thence over to the Delaware river; and thence up the same to the confluence of the Lackawaxen, and thence up the Lackawaxen to a point as near to the coal mines as possible and to ascertain the practicability and expense of a canal over that route." Under the general supervision of Wright two other canal engineers, John B. Mills of the Erie and John L. Sullivan of the Middlesex and Merrimack River Valley Canals, made the survey which was printed in January 1824. The report recommended that a canal 4 feet deep and approximately 32 feet wide at the water line be dug at a cost of $1,208,632.95, a fact that caused the company to increase its capital stock to $1,500,000.[5]

On March 8, 1825, the canal corporation was formally organized, Philip Hone, soon-to-be mayor of New York City, being elected president and John Bolton as treasurer. In June the Delaware and Hudson Canal Company purchased the Lackawaxen Coal Mine and Navigation Company. On July 13 Hone led the groundbreaking ceremonies for the canal at the

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4. LeRoy, Delaware & Hudson Canal, pp. 8-10.

5. Whitford, History of Canal System of New York, I, 732-34, and Report of Messrs. Benj. Wright and J. L. Sullivan, Engineers, Engaged in the Survey of the Route of the Proposed Canal, from the Hudson, to the Headwaters of the Lackawaxen River, Accompanied by Other Documents, & c (Philadelphia, 1824).

at the summit of the watershed between what are now the towns of Ellenville and Wurtsboro, New York. As construction began Wright was engaged as chief engineer of the undertaking with John B. Jervis, another of the Erie engineers, serving as his assistant.[6]

The canal was completed at a cost of some $1,875,000 by the fall of 1828 with the first boat, Orange Packet, traversing the waterway from Kingston to Honesdale in late October. The entire canal and the 17-mile gravity railroad which transported the coal from the Carbondale mines to the canal terminus in Honesdale were opened for business in October 1829, and some 7,000 tons of anthracite were carried over the line that year. On February 21, 1829, Niles' National Register printed a description of the canal as a waterway 32 to 36 feet wide at the water line and having

> four feet depth of water. The locks are 70 feet in length between the gates and nine feet wide. The boats are estimated to carry twenty-five to thirty tons.
>
> From the mouth of the Rondout, were [sic] it connects with the Hudson, to Port Jervis, near the Delaware River, is a distance of 59 miles; on this section are 60 lift locks and one guard lock of hammered stone, laid chiefly in hydraulic cement. There are also one aqueduct over the Neversink River 224 feet in length, upon stone piers and abutments; one over the Rondout, entirely of stone, upon two arches, one of 60 and the other of 50 feet chord; and ten others, of various dimensions, upon stone piers and abutments over lateral streams; 15 culverts of stone, and 93 bridges having stone abutments and wing walls.
>
> Port Jervis is less than a mile from Carpenter's Point, formed by the junction of the Neversink and Delaware rivers, and at which point . . . the line of the canal is carried along on the east side of the Delaware, to a point opposite the mouth of the Lackawaxen River. At this place a dam has been erected across the Delaware, by means of which the canal is fed, and boats cross the river. From McCarty's Point, which is formed by the junction of the Lackawaxen with the Delaware, the canal follows up the valley of the Dyberry, at which point the canal terminates, and where a thriving village is already established called Honesdale.

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6. Harlow, Old Towpaths, pp. 187-88, and Annual Report of the Delaware and Hudson Canal Company, 1825, p. 4.

> On the Delaware section of 22 miles, there are 13 wooden locks, and on the Lackawaxen section of 25 miles are 37 locks of the same description. These locks are secured by a substantial dry stone wall, and so constructed that the wood lining can be taken out and replaced, without disturbing the rest of the lock. . . .[7]

When the canal was opened its dimensions permitted the passage of boats having only a 20- to 30-ton capacity. With the supply of anthracite assured, the use of coal for heating, iron smelting, and steam generation expanded rapidly, thus contributing to an ever-increasing demand for more. As a result the canal had nearly reached its capacity by 1841 when 192,270 tons were carried on the waterway.[8]

With the profits from the first decade's expansion as well as an increased capitalization which was raised on a periodic basis to nearly $6,600,000 by December 1850 a series of improvements were undertaken in the 1840s to enlarge the capacity of the canal.[9] These improvements were under the supervision of Russel F. Lord, the canal company's chief engineer from 1830 to 1863.[10]

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7. Niles' National Register, February 21, 1829. Later in 1840 a description of the canal and gravity railroad was printed in Henry S. Tanner, A Description of the Canals and Railroads of the United States Comprehending Notices of All the Works of Internal Improvements Throughout the Several States (New York, 1840), p. 58. A copy of Tanner's description may be seen in Appendix A.

8. Century of Progress, pp. 124-25.

9. The financial success of the Delaware and Hudson Canal is analyzed in Arthur J. Alexander, "Cost Curves and Rate of Return on the Delaware and Hudson Canal, 1831-1899," paper prepared for American Economic History, Johns Hopkins University, 1966.

10. Century of Progress, pp. 126-27, 184. Background historical material on the canal improvements and enlargements from 1842 to 1850 may be seen in Chapter Six of this book. A well-researched biography of Russel F. Lord may be found in Peter Osborne III, "Russel Farnum Lord: His Life, His Times, and His Letters" (unpublished paper, Honors Program in American History, Rutgers, The State University, Newark, New Jersey, September 1982). In 1826 Lord had begun work for the company as an assistant to resident engineer Portius R. Root. Later

The first official mention of enlarging the canal was on March 24, 1841, when a committee of the board of managers reported that enlargement of the waterway was both desirable and necessary. Later in March it was determined that an aqueduct was needed near the mouth of the Lackawaxen River to carry the canal across the Delaware River--a decision that led to construction of the Delaware Aqueduct some six years later.[11]

The first program of improvements was authorized by the canal managers in August 1842. This enlargement called for dredging the trench and building up the height of the banks with the spoil to increase the dimensions of the canal prism to a depth of 5 feet and a width at the water line of 44 feet and at the bottom of 26 feet, thereby permitting passage of 40-ton boats. When the work was completed in late 1844 it was calculated that the sum of $108,438.87 had been spent on the improvements, but that the savings by loading existing boats with more coal had been $163,429.40.[12]

The benefits and the company's prospects led the canal managers to authorize another enlargement of the canal to a depth of 5-1/2 feet that would permit passage of 50-ton boats and thus extend the annual canal capacity to 500,000 tons. When the work was reported completed on November 17, 1847, the canal management observed that this second enlargement had cost some $265,000, while savings in the cost of transporting coal had exceeded that figure by some $232,000.[13] The

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10. (Cont.) during the summer of 1827 Lord became resident engineer of the Lackawaxen section of the canal and served in that capacity until replacing John B. Jervis as chief engineer in 1830.

11. Booth, "Delaware and Hudson Canal," p. 52, and Century of Progress, pp. 107-08.

12. Booth, "Delaware and Hudson Canal," pp. 52-53, and Century of Progress, pp. 126-28.

13. Century of Progress, pp. 128-29. The Annual Report of the Delaware and Hudson Canal Company, 1846, contains an extract of a report prepared by Russel F. Lord on January 6, 1847, in which he discusses the improvements made on the canal and their impact on its operation. A copy of this extract may be seen in Appendix B.

canal company also reported in 1847 that it had realized a net profit of $582,767 during the preceding year. This sum was "over 20 per cent on the capital paid in, besides expending 30,000 extra in damages by the freshet of the year 1846."[14]

The 1845-47 enlargement was recognized as largely inadequate virtually before completion as a result of the increasing demand for anthracite coal and the construction of the Erie Railroad into the Delaware Valley and toward the coal regions in the mid-1840s, thus ending the canal's monopoly of anthracite transportation. To compete with the railroad the canal was forced to operate as economically as possible, further reduce transportation costs and transit time, and increase boat capacity. Thus in late 1847 it was determined to enlarge the canal prism to a width at the water line of 48 feet and at the bottom of 30 feet and to a depth of 6 feet. This enlargement, which was estimated to cost $1,105,000, would accommodate boats having a 98-ton capacity and would double the annual carrying capacity of the canal to 1,000,000 tons. As a result all locks and aqueducts along the line of the canal were to be rebuilt, the former being enlarged to 15 feet by 90 feet. It was estimated that this extensive enlargement program would reduce the freight charges on coal to 50 cents a ton, "a reduction of over forty cents per ton on the lowest freight yet paid."[15]

The larger boats that such an enlargement would permit could be sent to all ports along the Hudson, supplying towns from the gate of the Mohawk Valley to the river's mouth, thus saving the expense of transferring cargoes at Rondout. Towed north to Albany, boats would be able to continue through the Erie Canal west to Schenectady, Utica, Syracuse, Rochester, Buffalo, and the Great Lakes market. Boats moving south to New York City could transfer their larger loads to brigs and schooners which sailed Long Island Sound to Connecticut towns and

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14. Niles' National Register, June 19, 1847.

15. Century of Progress, pp. 129-30, and LeRoy, Delaware & Hudson Canal, pp. 43-46.

proceeded through Narragansett Bay to Providence or around Cape Cod to Boston to meet the growing demand for anthracite coal in New England.[16]

16. Binder, Coal Age Empire, pp. 145-46.

CHAPTER TWO

THE DELAWARE AND HUDSON CANAL AT THE CONFLUENCE OF THE DELAWARE AND LACKAWAXEN RIVERS: 1829-50

Using the original canal survey by Wright that had been submitted in January 1824, the Delaware and Hudson engineers and surveyors completed their final surveys and estimates prior to construction in 1825. In their opinion the "best and least expensive route" was "an independent canal, instead of a canal in part, and a slack water navigation in the Roundout, Delaware, and Lackawaxen Rivers, and between the great rivers. . . ."[1]

As the canal was originally built, a small dam was constructed across the Delaware just below the confluence of the Lackawaxen River to create a slack water for the floating across of canal boats. The original canal works at the confluence of the Delaware and Lackawaxen rivers were described by John Willard Johnston, a long-time Delaware River Valley resident:

> . . . at Lackawaxen . . . it [the canal] passed through a guard lock into the Delaware. Opposite the guard a dam extended across the River, erected and maintained at heavy expense for the purpose of raising the water of the river and thereby feeding and supplying the canal, and this formed the only feeder thence to Mongaup, excepting some small streams flowing in at different points.
>
> The dam flowed the water of the river back to the distance of about 1 1/4 miles forming a beautiful sheet of water and at times of low water, calm and placid. A channel was provided for the passage of rafts and the height of water for the requirements of the canal was regulated by means of brackets across such channel, and removed when the volume of water in the river became excessive. Many times during extended droughts and the river becoming very low, extra means for preserving a sufficiency of water was resorted to such as graveling the dam; and when too high the guard lock was clossed [sic] and the canal fed through its gates.

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1. Annual Report of the Delaware and Hudson Canal Company, 1825, p. 4.

> A towpath was formed along the river edge a distance of half a mile or thereabout, to a point where a ferry was erected, by means of a pier stationed at the opposite sides of the river, composed of foot square pine timber, locked together at the corners and the interior thoroughly filled with stones. The piers were 12 feet square at the base, about 15 feet high and contracted to about seven feet square at the top; and these piers supported the ends of a ferry rope two inches in diameter, stretched across the river from pier to pier. By means of this rope a ferry scow was guided and towed back and forth across the river . . . the demands were so many that the scow was kept nearly in constant motion during the day and a portion of the night, many times. . . . The canal boats passing through the guard lock on the New York side, entered the Delaware and were towed to the ferry, by which the horses, the drivers and sometimes the boats were passed to the opposite side. On the Penna. side were six locks in close proximity, locking up from, or lower to the level of the river; the lower lock letting the loaded boats lower into the water of the river or raising light boats out of the said river to the level above. From this lock, a tow-path led to the Penna. end of the ferry. When the water of the river was at low mark, the boatmen . . . would by subjecting their bone to extra exercise, give force and headway enough to the boat . . . to shoot across the river, and thus avoid the slow, tedious process of pulling it across by rope.
>
> Many times the loaded boat crossing from the Penna. side, would pass over the river and enter the canal in New York before the horse and driver, crossing by the ferry would overtake.
>
> When however, the river was swollen by rains, the boats, horses and all must be crossed by the ferry, a slow, tedious, laborious process, requiring the strength of 3, 4 and 5 chosen men to be exerted upon the rope.
>
> Even this was possible only at certain grades of water, above which boats could not be crossed at all and the business of the canal suspended for the time. . . .[2]

During the next two decades the canal works at the confluence of the Delaware and Lackawaxen rivers posed a variety of problems for the

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2. J. W. Johnson, "Reminiscences and Descriptive Account of the Delaware Valley and its Connections Aiming to Extend from Pond Eddy to Narrowsburg Both Inclusive," 2 vols. (January 9, 1900), I, 38-42 (handwritten copy, Minisink Valley Historical Society, Port Jervis, New York).

Delaware and Hudson Canal Company. Not only did the slack water crossing prove to be the worst bottleneck along the line of the canal but ice and water freshets caused serious damage on a number of occasions, necessitating expensive repairs and endless turmoil, loss, and litigation as the result of altercations with the river raftsmen. After a freshet rendered the dam impassable in April 1829 a group of raftsmen, angry that the canal company did not immediately remove the obstruction, "proceeded to the dam, blew it up and tore away about eighty feet of it, and succeeded in clearing a passage for their rafts."[3]

Floods and ice freshets continued to plague the canal works in this vicinity. A flood and ice freshet in January 1831 "proved . . . destructive to property," sweeping "the ice with great violence out of the Delaware river" and causing "injury . . . to the apron of the Delaware dam."[4] During the spring of 1837 "unusually heavy" canal repairs were attributed in part to "the breaking up of the ice in the Delaware and Lackawaxen rivers. . . ."[5] Large repair expenditures were required after "an extraordinary flood" caused by an ice freshet on the Delaware River in March 1846 led to considerable damage along the "Delaware section" of the canal. During this flood the water was higher than it had been "during the great flood of 1841, which was so disastrous to the Lehigh and Schuylkill Canals, as well as our own."[6]

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3. National Intelligencer, April 18, 1829. This incident is described in more detail in an article in the Wayne County Herald, November 22, 1877, excerpts of which may be found in Sanderson, Delaware & Hudson Canalway, pp. 30-31. The excerpts may be seen in Appendix C.

4. Annual Report of the Delaware and Hudson Canal Company, 1831, p. 11.

5. Annual Report of the Delaware and Hudson Canal Company, 1837, p. 4.

6. Annual Report of the Delaware and Hudson Canal Company, 1846, p. 3.

CHAPTER THREE

DETERMINATION TO BUILD THE DELAWARE AQUEDUCT

The need for an aqueduct to carry the Delaware and Hudson Canal over the Delaware River had been understood from the canal's beginning. Tentative steps for such a structure had been taken in March 1841 when the canal managers directed Chief Engineer Russel F. Lord to locate an aqueduct at or near the mouth of the Lackawaxen to carry the canal across the Delaware River.[1]

The issue of constructing an aqueduct over the Delaware River again confronted the Delaware and Hudson Canal Company in January 1845 when the Erie Railroad began to make preparations to petition the Pennsylvania state legislature to permit it to enter the state over a bridge just north of the mouth of the Lackawaxen River. As a result Lord presented a proposal to John Wurts, the canal company's president, to enlarge the canal on the flats of the northern side of the Lackawaxen and to construct an aqueduct to carry the canal across the Delaware River where the rope ferry was located. He also proposed that the first three locks on the Pennsylvania side of the Delaware be eliminated and relocated on the New York side, where the canal could then follow its existing course. The purpose of Lord's proposal was to allow construction to begin immediately, thus forcing the railroad to be diverted away from the company's works and avoiding interference with the canal's own planned crossing of the river.

At this point the canal company confronted a second problem resulting from a Pennsylvania law passed on February 9, 1826, that prevented it from constructing an aqueduct across the Delaware River and diverting the water of the Lackawaxen beyond its normal course. Lord argued that the company would meet the spirit of the law, because the

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1. Century of Progress, p. 139.

water used in the aqueduct would actually be discharged from the New York locks into the Delaware River directly across from the mouth of the Lackawaxen. Because Wurts feared that the legislation permitting the railroad to enter Pennsylvania would be passed, he urged Lord to proceed with the construction of the aqueduct as quickly as possible.

Soon thereafter Lord presented a plan for an aqueduct across the Delaware River where the rope ferry was located. The specification called for a 600-foot-long structure having nine piers spaced at distances ranging from 53 to 70 feet apart. The wider spaces were to be placed on the deeper New York side of the river. Towpaths were to be located on both sides of the aqueduct, and the piers were to be 10 feet thick at the base and 4 feet thick at the top. The bottom of the superstructure was to be 26 feet above the level of the river, and the structure was to be built at right angles to the river. Stone for the masonry was to be obtained from local sites, cut, and laid in cement.

As Lord proceeded on the project he ran into difficulty with Benjamin Holbert, the landowner of the property, taverns, store, and houses on the north side of the Lackawaxen who was suspected of favoring the railroad's entry into the state. The canal company had the deed of cession from Holbert dating back to the 1820s for rights to the land that it crossed. The canal company's attorney, however, was of the opinion that the revised Pennsylvania constitution required corporations to provide adequate compensation to private property owners if they intended to infringe upon the property of the parties. Lord, agreeing with the counsel, was certain that Holbert would require extravagant sums of money from the canal company before he would allow his property to be used for enlargement of the canal and construction of the aqueduct.

Because of the intransigence of Holbert, Lord recommended purchase of part of the Lackawaxen Manor on the south side of the Lackawaxen River when Charles Lacoste placed the land on the market for $7,000 in November 1845. This would enable the canal company to skirt the Holbert lands by carrying the canal over to the south side of the Lackawaxen via an aqueduct and then over the Delaware south of the rope ferry site.

Accordingly, Lord quietly purchased 126 acres of the Lackawaxen Manor (known as the Lacoste Purchase) for $7,000 in January 1846 and then conveyed to the canal company the right "to use, occupy &c. these Lands" on October 7, 1846 (later on May 16, 1851, he quit claimed the land to the company by deed.)[2]

Thus, the proposed construction of the Delaware Aqueduct was both delayed and its location changed as the result of competition with Erie Railroad interests. Documentation relative to the delay and change of location, recently found by Peter Osborne III, Executive Director of the Minisink Valley Historical Society, in the Lord Collection and collaborated by the Weston Delaware and Hudson Canal maps explains the reasons why Lord, in planning the canal improvement at the confluence of the Delaware and Lackawaxen rivers, established the aqueduct over the Delaware not above the mouth of the Lackawaxen at the rope ferry site, but just below, thus requiring construction of a second new aqueduct over the Lackawaxen less than 1/2-mile upstream.[3]

Construction of the Delaware and Lackawaxen aqueducts was authorized by the canal managers on February 13, 1846, soon after the Lacoste Purchase was made.[4] By mid-December of that year two proposals for the Delaware Aqueduct had been received--one for a

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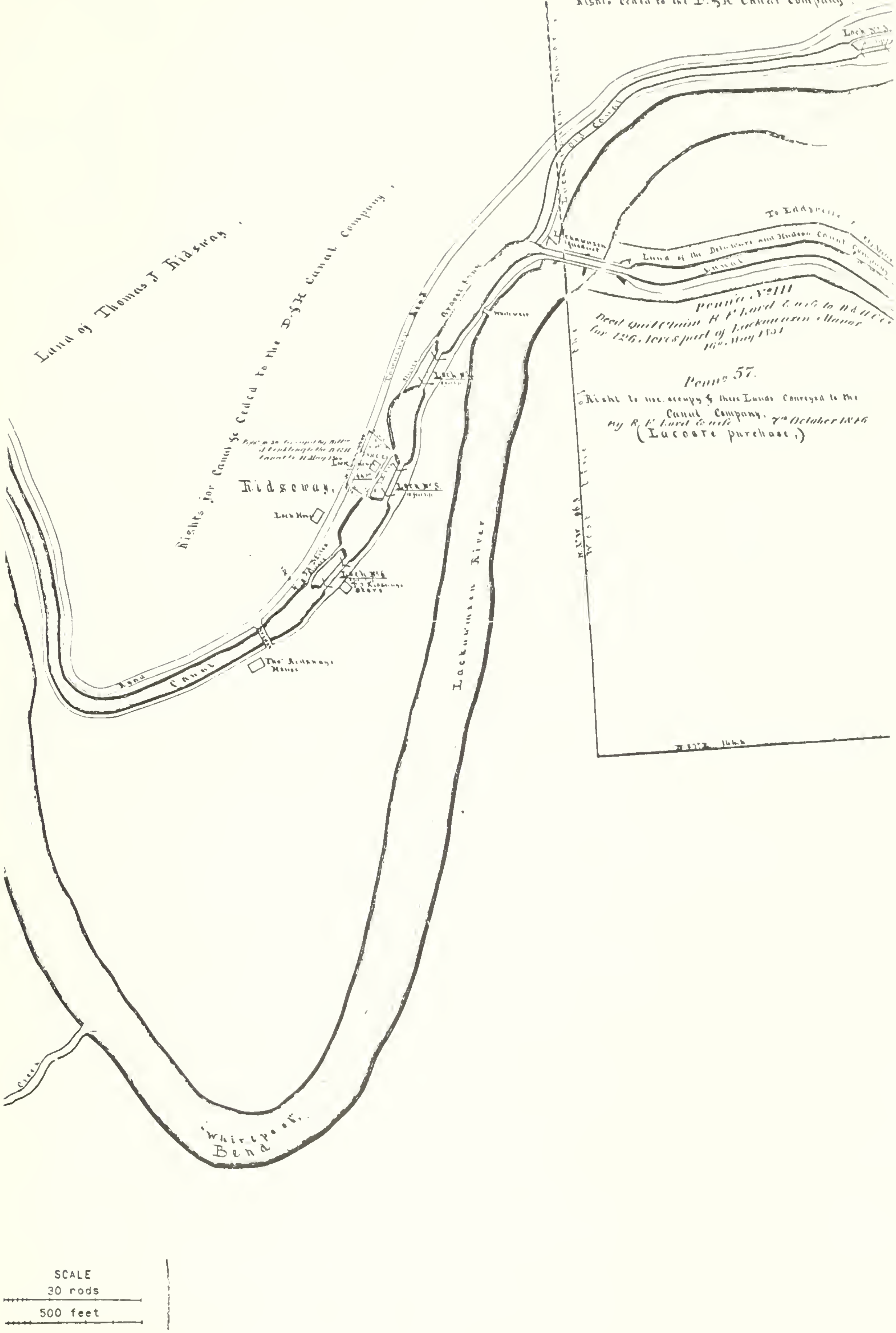
2. Material for this section is based on "The John A. Roebling & Delaware and Hudson Canal Years: 1844-1863," paper presented to the John A. Roebling Symposium at Eddy Farm, Sparrowbrush, New York, on June 4, 1983, by Peter Osborne III," pp. 5-8, and L. W. Weston, Delaware and Hudson Canal Company Maps, (surveyed in 1854 and drawn in 1856 by L. W. Weston, revised in 1865 by R. F. Lord, Jr.). The originals of these maps are in the possession of the Delaware and Hudson Railway Company in Albany, New York, and xerox photocopies are available in the Ellenville Public Library and Museum, Ellenville, New York. Copies of the maps of the area at the confluence of the Delaware and Lackawaxen rivers may be seen on the following pages.

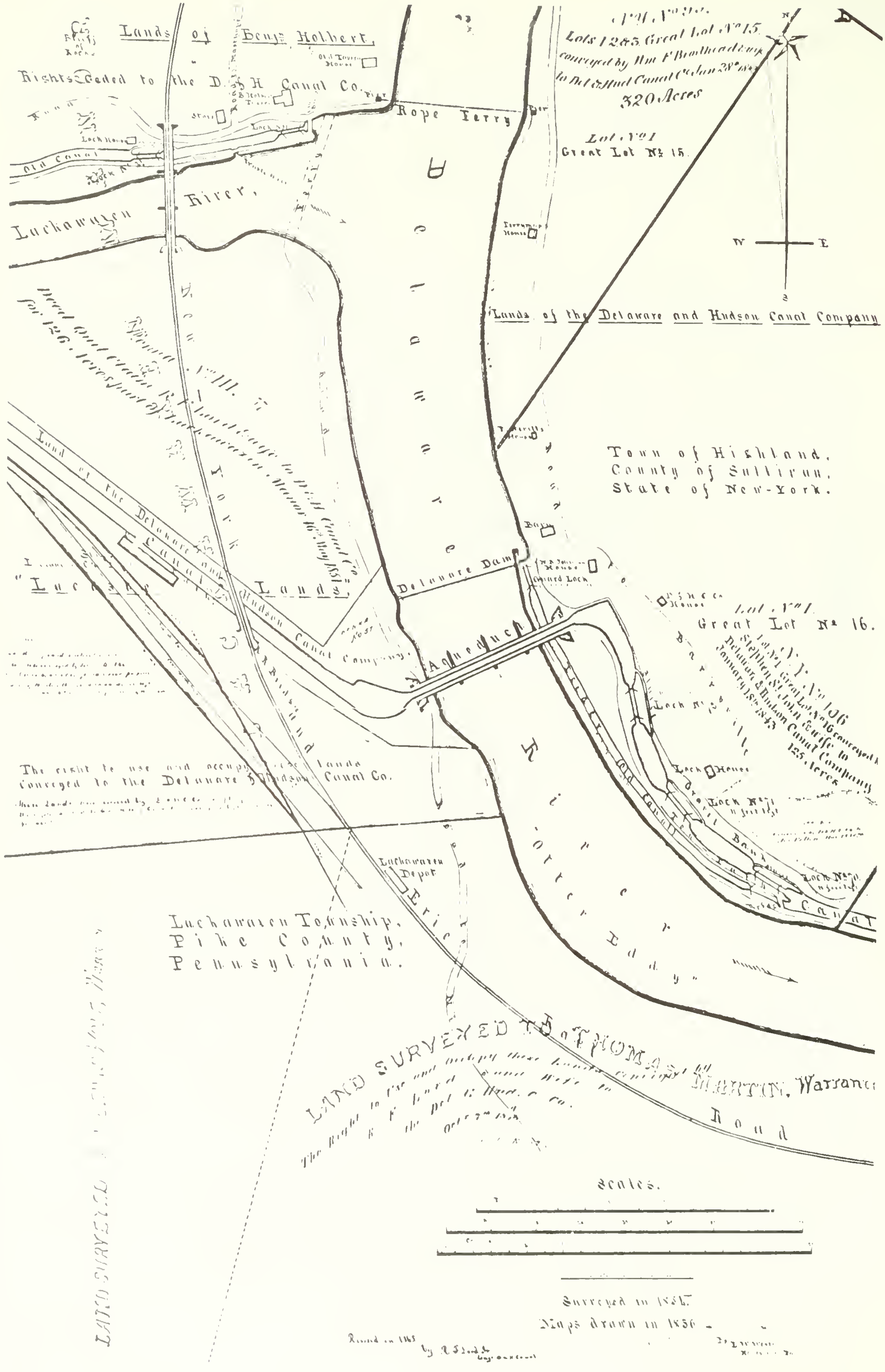
3. Previous explanations for the construction of two aqueducts and the change of the canal's route to the south side of the Lackawaxen are best summarized by Vogel, Roebling's Delaware & Hudson Canal Aqueducts, pp. 6-7, 9.

4. Century of Progress, p. 139.

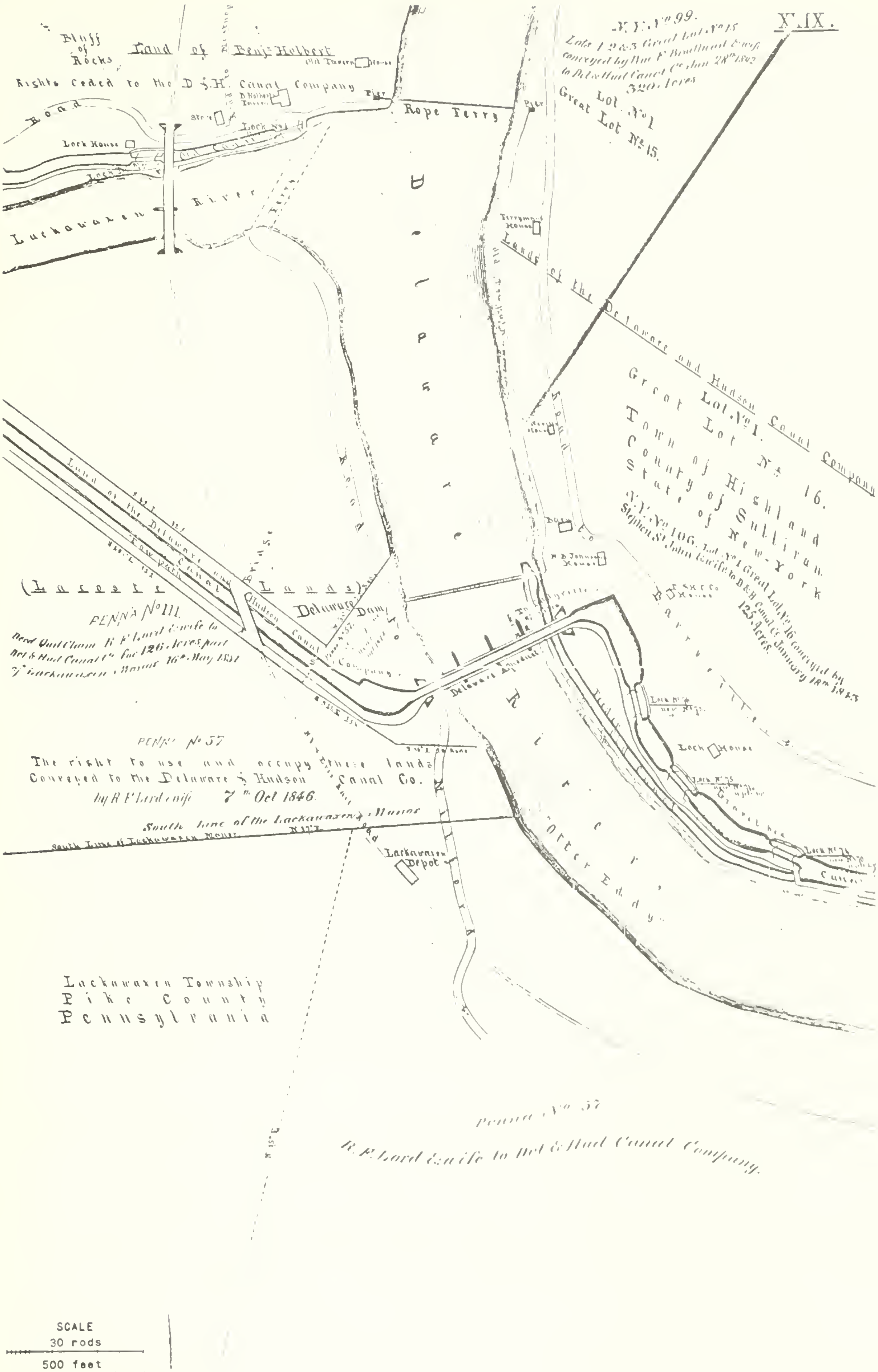
XXVIII.



Land of Benjn Holbert.
Rights ceded to the D.&H. Canal Company.
Lock No 3.
Canal
Lackawaxen Aqueduct
To Eddyville
Land of the Delaware and Hudson Canal Company
Canal
Penna. No 111
Deed Quit Claim R. F. Lord & wife to D & H C Co
for 126 Acres part of Lackawaxen Manor
16th May 1851
Penna. 57.
Right to use, occupy & these Lands Conveyed to the Canal Company,
by R. F. Lord & wife 7th October 1846
(Lacoste purchase,)
Land of Thomas J. Ridgway.
Rights for Canal &c ceded to the D.&H. Canal Company.
Ridgeway,
Lock House
Lock No 5
Lock No 6
The Ridgways House
Road
Canal
Lackawaxen River
Whirlpool Bend
Creek
SCALE
30 rods
500 feet



Lands of Benj. Holbert.
Rights Ceded to the D. & H. Canal Co.
Rope Ferry
Lots 1 2 & 3. Great Lot No. 15.
320 Acres
Lot No. 1
Great Lot No. 15.
Lackawaxen River.
Old Canal
N
W
E
S
Lands of the Delaware and Hudson Canal Company
Town of Highland,
County of Sullivan,
State of New-York.
Delaware River
New York
Land of the Delaware and Hudson Canal Company.
Delaware Dam
Guard Lock
Aqueduct
Lot No. 1
Great Lot No. 16.
125 Acres
Lock No.
Lock House
Old Canal
The right to use and occupy these lands conveyed to the Delaware & Hudson Canal Co.
Lackawaxen Depot
Erie
Lackawaxen Township,
Pike County,
Pennsylvania.
Otter Eddy
LAND SURVEYED TO THOMAS MARTIN, Warrantee
Road
LAND SURVEYED
Scales.
Surveyed in 1857
Maps drawn in 1856



X.IX.
N.Y. No 99.
Bluff of Rocks
Land of Benjn Holbert
Old Tavern
Rights ceded to the D & H. Canal Company
Road
Rope Ferry
Lock House
Lock No 1
Lackawaxen River
Lot No 1
Great Lot No 15.
320 Acres
Ferryman's House
Lands of the Delaware and Hudson Canal Company
Great Lot No 1.
Great Lot No 16.
Town of Highland
County of Sullivan
State of New-York
N.Y. No 106.
125 Acres
Delaware River
Road
Land of the Delaware and Hudson Canal Company
Tow path
(Lacostes Lands)
PENNA No 111.
Delaware Dam
Delaware Aqueduct
Lock House
Lock No 75
Lock No 76
Canal
PENNA No 57
The right to use and occupy these lands Conveyed to the Delaware & Hudson Canal Co. by R F Lord & wife 7th Oct 1846
South line of the Lackawaxen Manor
South Line of Lackawaxen Manor
Lackawaxen Depot
Otter Eddy
Lackawaxen Township
Pike County
Pennsylvania
Penna No 57
R. F. Lord & wife to Del & Hud Canal Company.
SCALE
30 rods
500 feet

conventional, trussed, six-span timber structure on masonry piers made by Solan Chapin. The other, submitted by John A. Roebling, a civil engineer from Saxonburg, Pennsylvania, was for a wire-cable suspension aqueduct to cross the river with four piers.[5]

In developing his proposed plan Roebling filled a notebook entitled "Wheeling Bridge, 1846, Delaware & Hudson Canal. [Aquaduct over] Delaware river. Aquaduct over Lackawaxen. Nov. 1846" with calculations, estimates, and drawings. A notation in the notebook for November 21, 1846, reads:

> Propose to Mr. R. F. Lord to construct both Aqua for the sum of $60,400 the large one [Delaware] with 8 1/2 inch cable, the small one [Lackawaxen] with 7 inch cables. The beams to be strengthened by susp. straps underneath, beams and posts to be preserved by tarring or painting, so that they will last 30 years. . . .[6]

Before the two plans were referred to a canal company committee for official consideration, John Wurts, president of the Delaware and Hudson Canal Company, studied and compared them. On December 17 he wrote to Lord:

> In regard to Roebling, I find that I have not information enough to enable me to make a comparison between his plan and the wooden aqueduct. In my memorandum book, it is offered that "the superstructure of the two aqueducts if of wood, would be $38,000. On Roebling's plan the cost would be $60,000--difference $22,000. The wooden structure would require repairs in 12 years; what is perishable in Roeblings would require repairs in 17 years--difference in duration 5 years, difference in cost of repairs $17,000 in favor of Roebling." Now to make a calculation between the two it is necessary to compound the interest on the $22,000 for 12 years to see what

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5. Booth, "Delaware and Hudson Canal," p. 53, and Proposal to Canal Company by S. Chapin, February 1846, Lord Collection, Minisink Valley Historical Society.

6. "Wheeling Bridge, 1846. Delaware & Hudson Canal [Aquaduct over] Delaware river. [Aquaduct over] Lackawaxen. Nov. 1846," Roebling Collection, Box 10, Folder 6, Richard Gelman Fixman Library, Rensselaer Polytechnic Institute, Troy, New York.

> funds we would then have in hand to repair the superstructure of the wooden aqueduct. Against this on the other hand, we must put the $17,000 that would be saved in repairs the first time, on Roebling's plan, together with five years interest compounded, on the whole amount that it would require to repair the wooden structure at the end of 12 years. Now this amount I have not got--I have merely difference between the two. If you will give me this amount I will make the calculation and then present the subject to the Board. . . .[7]

The two plans were referred to a company committee on December 28, 1846, and on January 6, 1847, the committee reported in favor of Roebling's proposal. Although expressing "much doubt" that the wire would be imperishable, the committee felt that it "must submit to the opinions of those who have examined the subject more fully." The principal advantage of the wire suspension bridge, in the opinion of the committee, was that two fewer piers would be necessary, thus making it cheaper, reducing its impedance to water and ice freshets, and providing for greater horizontal clearance for river traffic. Suspension spans could also be erected without falsework in the river, an important advantage at a site subject to flooding and ice floes. Their recommendation, however, was to take effect only after James Archibald, engineer of the canal's gravity railroad, or Russel Lord, chief engineer of the canal, inspected a similar aqueduct built by Roebling in 1844-45 to carry the Pennsylvania Canal over the Allegheny River at Pittsburgh.[8]

Lord arrived in Pittsburgh on January 29 to inspect both the Allegheny Aqueduct and Roebling's Smithfield Street suspension bridge built in 1845-46 over the Monongahela River. The Allegheny Aqueduct, erected in 1844-45 on the piers of a seven-span timber structure that had been damaged by ice, and the Smithfield Street Bridge over the Monongahela were the first bridges of any kind built by Roebling, who

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7. John Wurts to Lord, December 17, 1846, Lord Collection, Minisink Valley Historical Society.

8. Minutes of the Board of Managers, Delaware and Hudson Canal Company, December 28, 1846, and January 6, 1847, quoted in Booth, "Delaware and Hudson Canal," pp. 53-54.

previously had been involved in general civil engineering activities for canals and railway surveys and had manufactured wire ropes for haulage on the inclined planes of the Allegheny Portage Railroad, the Morris Canal, and the gravity railroad of the Delaware and Hudson Canal.[9] In his personal diary on January 29 Roebling wrote:

> Mr. Lord Engineer of the D & H CC arrived at Pittsburgh. Appeared to be well pleased with the aquad. & bridge.

When Lord left Pittsburgh on February 2, Roebling noted:

> Mr. Lord left Pittsburgh for Ph.--promised to write to Saxonburg, as soon as the contract was confirmed by the D. H C. Co.[10]

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9. A biographical sketch of John A. Roebling, as well as an examination of his accomplishments and contributions to bridge engineering technology, may be seen in Chapter Five of this report.

10. Diary (1847), Roebling Collection, Box 14, Rensselaer Polytechnic Institute. Contemporary descriptions of the Allegheny Aqueduct and the Monongahela Bridge at Smithfield Street in Pittsburgh that were printed in the American Railroad Journal may be seen in Appendixes D and E. Further information on the two bridges may be found in: "The Wire Suspension Aqueduct over the Allegheny River at Pittsburgh," Journal of the Franklin Institute, X (1845), 306-09; Henry Grattan Tyrrel, History of Bridge Engineering (Chicago, 1911), p. 219-20; J. C. Adams, "Multiple-Span Suspension Bridges," Engineering News - Record, CVII (August 13, 1931), 270; S. M. Wickersham, "The Monongahela Suspension Bridge at Pittsburgh, Pa.," Scientific American Supplement, XV (June 16, 1883), 6201-02; G. Lindenthal, "The Monongahela Bridge," Engineering News and American Contract Journal, XI (May 24, 1884), 251-53, and XI (May 31, 1884), 265-66; and D. H. Mahan, An Elementary Course of Civil Engineering, 6th ed. (New York, 1868), pp. 163-64, 172-76.

CHAPTER FOUR

CONSTRUCTION OF THE DELAWARE AQUEDUCT: 1847-49

The last entry in Roebling's diary referred to the fact that on February 1 he had given Lord a proposed specification for the Delaware and Lackawaxen aqueducts for approval by the company managers. A copy of the "Specification of the Superstructure of the Wire Cable Suspension Aqueduct over the Delaware River and Lackawaxen Creek, Delaware & Hudson Canal," dated February 1, 1847, and signed by Roebling in Pittsburgh, read:

> The aqueduct over the Delaware river will be constructed in 4 spans, one reach to be 142 feet wide from centre to centre, the others to be 131 feet each. The Lackawaxen aqueduct will consist of two equal spans of 115 feet from centre to centre.
>
> Both works are to be constructed upon the plan of the suspension aqueduct over the Allegheny river at Pittsburgh, with those exceptions mentioned below. The cables on the Delaware aqueduct are to be 8 1/2 inches diameter; one on each side of the trunk; those on the Lackawaxen will be 7 inches diameter; the anchor chains will be in proportion. The cables will be manufactured of the best charcoal iron wire, No. 10 size, the wrapping No. 14 1/2 do. Each strand of wire to be well varnished, and the whole cable to be well painted inside and outside. The anchor chains will be manufactured either of good charcoal blooms, or good scrap iron. They will be well painted before they are put under ground, and surrounded by hydraulic cement (to be furnished by the Company.) The cables will rest and be secured in cast iron saddles on the piers. Those on the abutments will be moveable, on rollers, to admit of contraction and expansion. The suspenders will be made of good charcoal iron, 1 1/4 inch diameter. They will be double, like those on the Pittsburgh aqueduct, and rest upon the cables by means of small cast iron saddles, which are to be connected among themselves by links, varying in size from 1 1/4 inches square to 1/2 inch.
>
> The trunk will be 9 feet deep, 18 feet in bottom, 19 feet at top water line, calculated for 5 feet 6 inches to 6 feet of water: to be composed of a double course of 2 1/2 inch planks, laid diagonally, the two courses crossing each other, and to be well spiked down. The bottom courses will be supported by the beams, the sides by the posts and braces. These timbers will be connected in solid frames, suspended to the cables, 4 feet apart from centre to centre. The beams and

braces will be arranged in pairs, the posts single. Each single beam will be 30 feet long, 6 x 15 inch. The trunk posts are to be 7 x 14 at the lower end and 7 x 7 at the upper. The outside posts and raillings [six] will be 7 x 7, the braces 2 1/2 x 10. The trunk posts will be secured between the beams by means of dovetailed tenons and screw bolts. The trunk posts as well as the outside posts to be extended above the towpaths for the support of the railings. There will be a towpath on each side of the trunk, 6 feet wide in the clear between the raillings [sic], to be constructed of two courses of plank, the lower course 2 inches, laid lengthways, the second course of 2 1/2 inches, laid across, all well spiked down, and resting upon joists of 2 x 10 inches, embracing the posts.

In order to assist the beams, they will be supported in the centre by a girder of 10 x 12 inches, resting upon oak blocks and iron straps, one on each side, 1 inch square. It is calculated that one half of the weight of the water will be supported by the straps, the other half by the timber. To make the trunk water tight and preserve the timber, both courses of the planking, bottom as well as sides, are to be well caulked and pitched for a depth of 6 feet and 6 inches.

The top of beams, as far as the bottom of trunk rest on: the inside of the posts, supporting the sides of the trunk; and the tenons of the posts will be painted with boiled linseed oil and spanish brown. The railings above the towpaths will be painted in the same way, except the crosses in the outside railing, which will be painted white.

The extension at the ends of the aqueducts to be constructed of a double course of planks, the lower course to be 2 inches thick, the upper courses 1 1/2 inch, sills, posts and braces to be of white oak, the sills to be hewed on two sides. All the timber and plank, except that of the anchorage and what is specified to be oak, to be of good sound white pine, and free of shakes, rents or black knots. The timber to be used in the anchorage will all be good sound white oak.

The drawings to be forwarded will more minutely explain the details of construction, and shall be considered a part of this specification.

I agree to put up the superstructure of the Delaware & Lackawaxen Aqueducts, as explained by this specification and the drawings, including all the timber, iron and wire-work, and caulking and painting, and furnish all materials, for the sum of <u>Sixty thousand and and Four hundred dollars</u> /$60,400/--the D & H Canal Company to do all the masonry of the piers and abutments, also the excavation and masonry for the anchorage, the excavation and puddling for the sheet pilings at the extension, stone cutting for bull heads and studdings, and furnish all the cement required for the anchorage and rest of the work.

> Payments to be made to the contractor, as the work proceeds, and materials are delivered. Ten percent of the contract sum to be retained by the Company, and to be paid to the contractor three months after the completion of the work.
>
> Signed John A. Roebling.
> Pittsburgh Feby. 1, 1847 [1]

In May 1846 George Watson, a friend of John B. Jervis, had been hired by Lord to begin preparations for the masonry of the Delaware Aqueduct. On February 2, 1847, Lord received a letter from Thomas Tracy who was supervising the work from his office at Lackawaxen. Among his comments were:

> The work at this place is going on very well. Although there is considerable frost to contend with this week it does not materially hinder Silas but Mr. Watson's force more where he is takeing [sic] out sand on the flat. The stone quarry work well. Mr. Fuller thinks he will be reddy [sic] to commence the excavation for the abutment to the aqueduct on the York side in about 2 weeks.

The cost estimate for work during January and February, including lumber for lock gates and the reservoir at Wilcox Pond, was $4,298. The cost estimate for the preliminary work at the Delaware Aqueduct site was $7,299 for the months of December 1846 and January and February 1847. The work for the aqueduct was under the supervision of three foremen: Watson, Huntington, and J. B. Fitch.[2]

On February 12 John Wurts informed Roebling that his proposals and specification for the Delaware and Lackawaxen aqueducts had been accepted by the company. The contract approval was subject to the understanding

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1. "Specification of the Superstructure of the Wire Cable Suspension Aqueduct over the Delaware River and Lackawaxen Creek, Delaware & Hudson Canal . . . February 1, 1847," Lord Collection, Minisink Valley Historical Society. A copy of part of the specification may be found in "Wheeling Bridge, 1846. . . ," Roebling Collection, Box 10, Folder 6, Rennselaer Polytechnic Institute.

2. Tracy to Lord, February 2, 1847, Lord Collection, Minisink Valley Historical Society.

> that the needful work is to be commenced as soon as the masonry which is to be constructed by this Company shall be completed to sustain the superstructure, and prosecuted to completion without any unreasonable delay to the satisfaction of R. F. Lord and James Archbald Engrs., the engineers of this company, or those who may succeed them in that station.

Roebling replied immediately that these terms were acceptable and the contract was closed.[3]

Roebling immediately started preparations for construction of the two aqueducts. On February 13 he sent to Lord a "cross section of the aquaduct [a copy of which has not been found] and a bill of timber."[4] Five days later he forwarded to Lord a preliminary cross section profile of the Delaware Aqueduct and asked for "two Cross Sections or profiles of the Riverbed and the Banks of the sites of the Deleware as well as the Lackawaxen Aquaducts." To provide a correct plan of the anchorage Roebling needed the profiles for the two banks at both sites. Because the river bed was "of less importance" and required less "accurracy" Lord could probably draw a rough section in his office without going to the site. Roebling also desired "a little topographical scetch [sic] of the two sites with the adjacent ground, & . . . drawn by hand without any scale." He went on to state:

> In the plan I sent you last week, you will observe that the trunk posts are extended 2' 6" below the beams. I should prefer to extend them 2' 9". The length of posts in the bill is 16 feet, long enough to project them 2' 9". I prefer this plan to the other. The iron rod will be calculated to support the truss, which results from one half of the weight of water.

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3. John Wurts to Roebling, February 12, 1847, and Roebling to John Wurts, February 19, 1847, Lord Collection, Minisink Valley Historical Society, and Roebling to John Wurts, February 19, 1847, "Wheeling Bridge, 1846 . . ," Roebling Collection, Box 10, Folder 6, Rensselaer Polytechnic Institute.

4. "Wheeling Bridge, 1846 . . ," Roebling Collection, Box 10, Folder 6, Rensselaer Polytechnic Institute.

> Please order one pair of beams and two trunk posts and 20 ft. braces, to be delivered early this season, for an experiment I wish to make, to convince all parties of the sufficient strength of the framing. I intend to put up 2 beams and posts, and load them with a quantity of stone, equal in weight to the weight of water. By carefully noting the deflection of the timbers, we are able to judge of their strength. I have done the same on the aquaduct, to test my calculations.

Roebling also enclosed another bill of timber

> including the oak required, except the timber from the anchorage, extensions and the oak suspension blocks. With respect to the beams, you better order them 16 inches x 13 1/2 inches, well squared and hewed, to be whip sawed by myself. The shorter timbers, particularly the posts I should prefer them sawed, this will be the cheapest and easiest way for the construction, if he has an opportunity for sawing. . . .[5]

On February 23 a circular was printed soliciting bids for lumber for the two aqueducts. The bids would be received until March 10 and the lumber was "to be of good sound White Pine, and work full size, free of shakes, rents or black knots, when counter-hewed." The lumber was to be delivered "on the Pennsylvania side of the Delaware river above high water mark, between the mouth of the Lackawaxen and Delaware Dam . . . by or before the first day of July next."[6]

Meanwhile, on February 18 Roebling wrote a letter to Jonathan Rhule, a resident of Williamsport, Pennsylvania, who had worked for Roebling during the construction of the aqueduct and bridge in Pittsburgh, asking him to be the on-site supervisor for the construction of the two aqueducts. Roebling noted:

> . . . I am now making plans, and have already forwarded bills of timber, which will be contracted for by the Engineer of the Cy. and delivered during the season but not until after the

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5. Roebling to Lord, February 18, 1847, Lord Collection, Minisink Valley Historical Society.

6. A copy of this circular may be seen on the following page.

LUMBER

WANTED, on THE DEL. & HUDSON CANAL.

PROPOSITIONS

Will be received until the 10th day of March next, for furnishing and delivering the following bill of Lumber, viz:

890	Pieces,	16 by 6 1-2 inches,—31 feet long,	104,910	feet Board Measure,
400	do.	14 by 7 inches at one end, 7 by 7 at the other,—16 ft. long,	39,200	do.
200	do.	7 by 13,—20 feet long,	30,400	do.
800	do.	2 1-2 by 10,—10 feet long,	16,~~800~~ [illegible]	do.
800	do.	2 by 10,—7 feet 8 inches long,	10,200	do.
400	do.	7 by 7,—12 feet long,	19,600	do.
400	do.	6 by 7,—6 feet 3 inches long,	8,~~800~~ [illegible]	do.
		1,600 feet Linial Measure, 7 by 7 inches, for Railing,	6,533	do.

1,600 feet Linial Measure,	6 by 6 inches, for Railing,	4,800	feet Board Measure.
1,400 do.	6 by 7, any length over 20 feet,	4,900	do.
1,400 do.	5 by 5, do.	1,450 2,916	do.
Plank, 25 or 26 feet long, 2 1-2 inches *uniformly* thick,		76,680	do.
Plank, 14 feet 4 inches long, 2 1-2 inches *uniformly* thick,		76,680	do.
Joice, 2 in. by 10, or 2 inches by 12, either 16, 20, or 24 ft. long,		22,400	do.
Joice, 1 1-2 by 10 inches, 16 or 24 feet long,		19,200	do.
Total Board Measure of Pine,		442,558	feet.

All the above bill to be of good sound White Pine, and work full size, free of shakes, rents or black knots, when counter-hewed, and delivered on the Pennsylvania side of the Delaware river above high water mark, between the mouth of the Lackawaxen and Delaware Dam (for Del. and Hud. Canal) by or before the first day of July next. Payment will be made when the Lumber is delivered on the bank as above stated, and approved and accepted to the satisfaction of the Engineer on Delaware and Hudson Canal for the time being. Proposals are desired to be in writing, stating the price per one thousand feet board measure, and directed to the subscriber, at the office of the Delaware and Hudson Canal Company, in Honesdale, Wayne county, Pa. For any information relating to the above bill of Lumber, apply to the Engineers or Superintendents on Delaware and Hudson Canal.

JOHN A. ROEBLING, *Engineer*.

February 23d, 1847.

June freshet. If we therefore go from here about the middle of June, it will be time enough. My calculation is to employ but a limited number of good carpenters, as there will be all the time from July and August to March next year doing the carpenter work. The anchor masonry is to be done by the Co., but I have to attend to it. The beams will have to be counter hewed. I intend freighting a section boat at Pittsbg. with tools and machinery. You and your family and some hands who wish to go along, can take passage at Hollidaysbg.

As to yourself, I will make you the following proposition:

I will pay you $2.00 per day, as long as the work lasts, which will probably be about one year, and an extra compensation of $100 besides, which I intend to increase to 200 more, if your conduct justifies it, but which increase shall entirely be left to my option and full will. If I fare well in the contract and am ably assisted by you, and you look to my interests--it will then give me much pleasure to reward you accordingly. . . .[7]

On March 6 Roebling submitted a bill of "white oak" for the anchorages of the two aqueducts to Lord. In a notation beneath this bill in his notebook, entitled "Suspension Aquaducts. Delaware and Hudson Canal . . . Feb. 1847," Roebling commented:

to avoid the corroding effect of the tauning and galling stuff, contained in oak, the first course of plank upon the anchor plates should be of maple wood or any other hard wood, which is free of corroding substance. Pine is too soft. Tarring the plank is also good. A layer of cement is also necessary between the plank and the iron. Avoid all contact of iron and oak timber. Lime is the best preventive. Lime water around the screws of the suspension blocks. The seat of the suspension plates should be well tarred, before the plate is put on. Mallet says that iron oxide in contact with iron, facilitates corrosion. If so what effect has Spanish brown, when the oil disappears.[8]

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7. Roebling to Rhule, February 18, 1847, "Wheeling Bridge, 1846 . . ," Roebling Collection, Box 10, Folder 6, Rensselaer Polytechnic Institute. Soon thereafter Rhule accepted the proposal.

8. "Suspension Aquaducts, Deleware and Hudson Canal. John A. Roebling, Febr. 1847," Roebling Collection, Box 4, Alexander Library, Rutgers, The State University, New Brunswick, New Jersey.

On March 15 Lord sent "rough sketches of the locality of the two aqueducts" which he had drawn on February 27. These drawings provided detailed data on the bank and riverbed conditions that Roebling had requested for preparing working drawings.[9]

Roebling made several notations in his notebook on March 11. One concerned his remark to Lord "that the foundation timber need only be flatted on both sides, and be 12" thick after counter hewing. The breadth is not material. I will square it myself and can work it to better advantage." He also commented that oak timber was ordered for the suspension blocks and that the trunk posts had been changed to "16' 4" long 15 x 7 & 7 x 7." Lumber had also been ordered for "shanties":

> 3000 sup. feet inch Boards 10 ft. long
> 1000 " " 2 inch plank 20 ft. long
> 400 lineal feet scantling 5 x 5, 20 and 36' long to be common stuff on fence.[10]

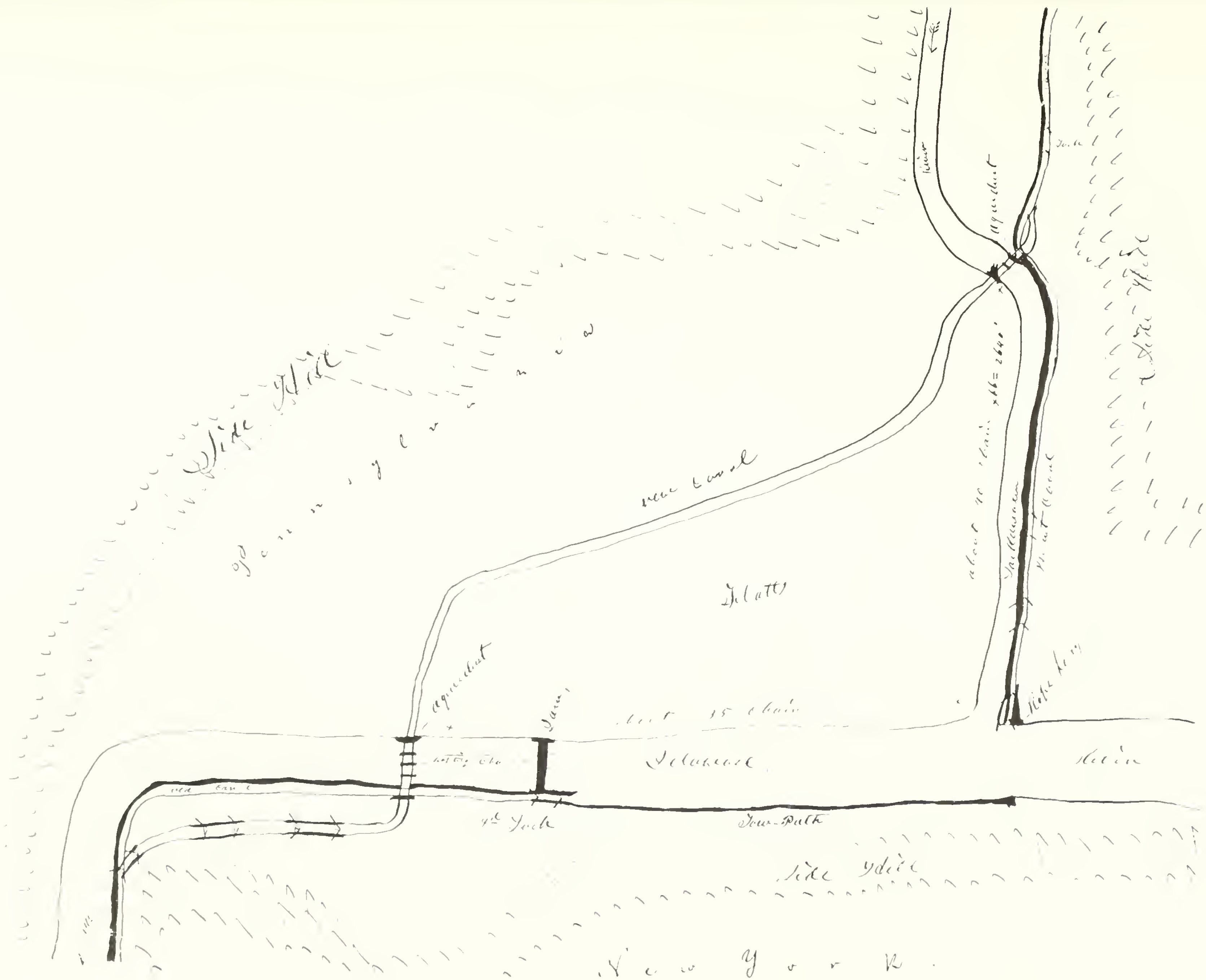
After reviewing proposals submitted in response to the lumber circular Lord let a contract to Lenaz H. Russell on March 15. The terms of the agreement, which included additions to the February 23rd advertisement, were:

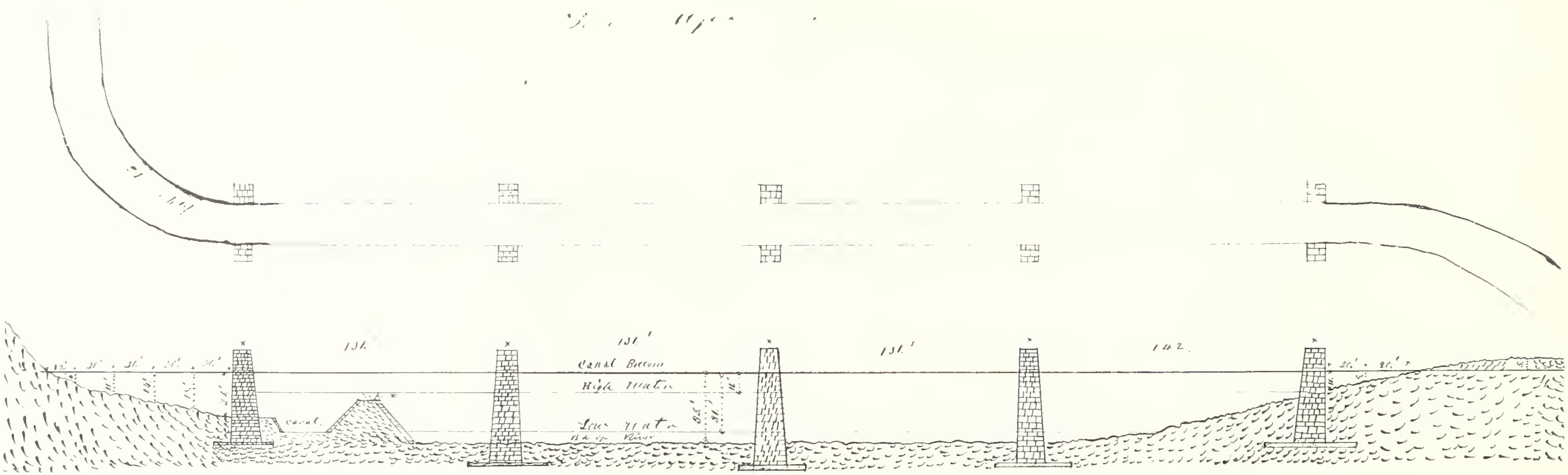
> to furnish the white pine lumber, agreeable to his [Roebling's] advertisement dated February 23d 1847 at the rate of Eighteen Dollars per one thousand feet Board measure . . . that you will deliver the thirty two hundred feet running measure contained in said advertisement for Railing, in pieces of from twenty five feet to forty feet in length, and that you will deliver in addition to the said advertised Bill, 30 pieces, 6 x 16 inches 18 feet & 6 inches long & 30 pieces 6 x 16 inches, 14 feet long, containing about 7,800 feet Board Measure of white pine of same quality & at the same rate--

---

9. Lord to Roebling, March 15, 1847, Correspondence (1847), Roebling Collection, Box 10, Folder 4, Rensselaer Polytechnic Institute. A copy of the drawings, located in Roebling Collection, Drawer 4, Folder 4, Rensselaer Polytechnic Institute, may be seen on the following pages.

10. "Suspension Aquaducts . . . Febr. 1847," Roebling Collection, Box 4, Rutgers, The State University.


Pennsylvania
Side Hill
new Canal
Flatts
Aqueduct
Dam
about 35 chains
Delaware
River
Tow-Path
Side Hill
New York
about 40 chains 66 = 2640
Aqueduct
Lackawaxen
River



Delaware Aqueduct.

{The view is, (Standing on the up Stream Side and looking down the River, with the Pennsylvania Shore on right hand.)}

The High water mark, is the highest point that ice has ever reached, and that on unusual flood and damming up of ice.

Common floods do not overflow the towpath bank as laid down on Newyork Shore. —

Newyork Shore,

On this Shore, the last Span stretches over the guard Bank & towpath; the present Canal, (which will be used for a feeder after the aqueduct is completed) and a hol Path next to the abutment. The Bank & Canal at this point, will be overflowed by Extra-ordinary floods and afford water way for the River. The measurements are taken below Canal Bottom; at the abutment the ground is about 28 feet below Canal Bottom, and Slopes up to Bottom in about 90 feet. Thence the hill rises more bold, and approaching nearer the river as you go down ~~the River~~ it.

There will be a bold curve soon as practicable after passing the aqueduct, and then Locks to connect with the Canal soon as convenient.

Pennsylvania Shore,

On this Shore the ground at the abutment is about 11 feet below Canal bottom, and Slopes up to bottom in about 50 feet, and thence about 50 feet more it reaches about 5. feet Cutting. This Shore is uniform about as laid down, and there will be a gentle Curve soon after leaving the aqueduct. The Slope of ground between the abutment and Pier will be excavated and increase the water way for the River.

Paved Washway in towpath at each end of Aqueduct.

And also that you will furnish at the same place the following Bill of good white oak lumber, and at the same time, for fifteen Dollars, per one thousand feet Board Measure--

32 pieces 7 x 12 inches 15 feet long--3,360 feet Bd. Meas.
30 pieces 8 x 12 inches 11 feet long--2,640 feet Bd. Meas.
45 pieces 3 x 7 inches 12 feet long--945 feet Bd. Meas.[11]

Under the direction of Lord plans for the masonry were well underway by March 19. On that date Lord wrote to Roebling:

> We have concluded to change the batter of our masonry to about one half inch to one foot, instead of one inch to the foot. We find that the half inch batter will save us considerable expense in dressing stone. We will carry it up a full and liberal level, as to thickness, and it will be conveniently brought to the proper, and desired dimension for connecting with your work. . . .

In that same letter Lord responded to certain questions Roebling had submitted to him along with some plans for the aqueduct. Lord commented:

> In relation to "how much the surface of Delaware & Lackawaxen rivers, is below canal bottom," I take the top of bottom plank in the aqueduct for canal bottom.
>
> During the summer and fall, when not swollen by heavy rains, what we call common water; the surface of Delaware river is about 31 feet below canal bottom: for both abutments the site is inland and through considerable excavation, and the foundation of both are nearly on a level with the common surface of the river, one being 32 feet below canal bottom, and the other which is on the canal side of the river 31 38 below. . . .
>
> Now for the abutment on canal side, you will observe that the depth of water in the old canal, will be, at that point about 6 feet above the foundation of abutment, that is, the surface of canal water will be only 25 38 feet below canal bottom, in the aqueduct, and your anchorage being 28 feet below will consequently extend 3 feet nearly below top of water. I have anticipated this to some extent by putting a sheet piling

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11. Lord to Russell, March 15, 1847, Correspondence (1847), Roebling Collection, Box 10, Folder 4, Rensselaer Polytechnic Institute.

> between the canal and abutment, in order to be able to pump out the water in case we should not get the abutment built up to top water before opening our canal, and this would enable us also to keep the water out while the anchors are being put down. I do not think the water would interfere enough to be of any consequence, unless you should deem it best to have the anchor plate placed so as to be permanently above the surface of the canal water, which will always be about 6 feet above the foundation of abutment, at that place; It will you are aware be maintained as a feeder after the aqueduct is completed.
>
> The surface of common summer & fall water in the Lackawaxen is 22 feet below canal bottom and both abutments will stand in the same relation to it. The foundation of those will probably be some 3 to 5 feet below the surface of water as we may find the material when we make the excavation for them.

Lord also noted that he was soliciting propositions "for getting the oak anchor timber." He feared it would be difficult "to procure the 100 sticks 42 feet long at this season of the year, unless at a high price" of "$25 to $30 per 1,000 feet Bd. measure." Boat building and shipping plank required by New York interests had "used up all that kind of timber that is nearby." He thought he could procure white or yellow pine more easily if those were suitable to Roebling.[12]

In answer to further questions from Roebling, Lord informed him on March 22 that "we are now putting down the foundation for Dela. Aqdt. abutment on NY side." On the Pennsylvania shore "the excavation for Dela. Aqdt. will be about 15 feet through sand, gravel, & loam, then about 10 feet through the same kind of material cemented so as to make nearly hard-pan intermixed with boulders." In his opinion this would not cause insurmountable difficulties for the excavation work for the anchors. On the New York side the excavation would "be easy, through loam & gravel." For the Lackawaxen aqueduct the excavation would "be gravel down to [the] surface of the river, below that, probably boulders." Lord was hoping "to get the abutments for Delaware Aqueduct in a state

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12. Lord to Roebling, March 19, 1847, Correspondence (1847), Roebling Collection, Box 10, Folder 4, Rensselaer Polytechnic Institute.

of forwardness so that the anchors may be put down soon after lst of July; and have the piers all done so that you can have a chance to commence the superstructure in the fall and pursue it during the winter." At the Lackawaxen he anticipated getting one abutment and the pier completed in the fall but the other abutment would not be finished until the winter. Waste weirs would be built by the company near the aqueducts. While Roebling had recommended that the canal company hire a Mr. Skew to superintend their works, Lord commented that John B. Jervis had already hired a superintendent who had worked on the Croton Aqueduct. A number of laborers from that project in New York City had also been hired to work on the two aqueducts.[13]

Some unexplained changes were made in late March relative to the lumber for the anchorages. On March 26, Roebling noted that he had informed Lord that "if the oak for the anchorages cannot be had at the rate of 12 cs. to 14 cs. p. ft. on 10.00 [by] 12.00 p. 1000, hewed he should order good hemlock 12 x 15 or 12 x 14--100 sticks 42 ft. long, hewed square." Two days later Roebling submitted a revised "Bill of Timber for 4 Anchorages" as follows:

	B. M.
28 sticks of Pine 42' long 12" x 15" square for Delaware	17,640 ft.
28 sticks of Pine 42' long 12" x 14" square Lackawaxen	16,464 ft.
60 sticks of Pine 32' long 12" x 14" square (D & L)	26,880 ft.
48 sticks of Pine 15' long 12" x 14" square (D & L)	10,080 ft.
Total pine	71,064 ft.
64 sticks white oak 14' long 10 x 12 for both	6,960 ft.
1600 " of 3" White Oak plank, 8' long, Bd. measure	4,800 ft.
400 " of 1 1/2" plank beach on maple, 8' long	600 ft.
Total Oak &	14,360 ft.[14]

13. Lord to Roebling, March 22, 1847, Correspondence (1847), Roebling Collection, Box 10, Folder 4, Rensselaer Polytechnic Institute.

14. "Suspension Aquaduct . . . Febr. 1847," Roebling Collection, Box 4, Rutgers, The State University.

Meanwhile, Roebling was making contacts relative to the purchase of metal components for the aqueducts. On March 27 he wrote to Everson & Co., operators of the Pennsylvania Forge:

> Since I saw you, I got the prices of Williams, Foster & Co. of the Temperanceville Forge, who charge for levers, straps & piston rods and such work, weighing from 1 to 200 lbs.--6 1/2 cs. per lb., all common work under 100 lbs., as pins & 6 cs. p. lb. I have no idea of employing that firm, but wish you to do my work, and request you to prepare at once for a job of about 60,000 lbs. I should like to have all finished by the 1st of June. But I hope you will be able to reduce your price from 7 cs. to 6 1/2 p. cs. for the bars--6 cs. for the pins. I have to pay 7 cs. freight. . . . I am now getting the patterns made for the bars, and can send you enough to commence in a week hence. . . . The iron to be the best quality of scraps or blooms, I prefer the scraps. . . .[15]

In March 1847 the canal managers reported that "considerable progress" had been made in the erection of the two aqueducts. The two structures would

> prevent the interruption which has frequently occurred in the navigation of the canal, in consequence of high water during spring and fall floods. It will also shorten the canal about half a mile, and place a portion of it on a higher level, thereby protecting it from inundation, to which it has heretofore been exposed, and from which it has frequently sustained serious injury.

Already some $23,932.74 had been spent on the structures.[16]

During the next six to eight months Roebling continued to finalize his plans, estimates, and calculations for the construction of the two aqueducts. His notebook for this period ("Suspension Aquaducts . . . Febr. 1847") contains data and sketches relative to the length of suspenders, quantities, cables, and chains for the two structures.

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15. Roebling to Everson & Co., March 27, 1847, "Wheeling Bridge, 1846 . . ," Roebling Collection, Box 10, Folder 6, Rensselaer Polytechnic Institute.

16. Annual Report of the Delaware and Hudson Canal Company, 1847, p. 5.

The only other documentation pertaining to the construction of the two aqueducts during the spring, summer, and early fall of 1847 is found in two ledgers entitled "Ledger. John A. Roebling. Aquaduct. Monongahela Br." and "Cash Book. John A. Roebling. Deleware & Hudson Aquaducts. July 1847 to June 1850." Citations in the "Ledger" indicate "castings" and "patterns" for the two aqueducts were prepared at Roebling's Saxonburg works and by P. & C. Shavers at the Alleghenytown Furnace during the period from June to October. That same summer anchor chains, pins, bars, and scraps were purchased from Everson & Co. of the Pennsylvania Forge for the aqueducts. On July 24 James Patterson of Pittsburgh was paid $380 for "drilling 20 set of bars for Delaware Aquaduct," "turning 20 pins," and "making 4 wrapping machines 8 1/2 inch diameter."[17]

The "Cash Book" indicates that Roebling purchased "wire" from Sherman & Morris and Phelps Dodge & Co. during August and from Jaafe & O'Connor in October and had it sent to Saxonburg. A small amount of wire rope was also purchased from one Archibald in September, as well as some iron from a Mr. Wetmore. Anchor bars, costing $1,800, were received from Everson & Co. on October 8. In addition a variety of supplies were purchased from August to October, presumably for his construction office and the workers at the site of the aqueducts: a stove from Palmer & Stanton of Honesdale; hanging papers from H. Ahrenfeldt; dry goods from Ovenon; provisions from Suydam Reed; tinware from Rockford & Worley; crockery from Frederick Hadley; and groceries, meat, vegetables, and other foodstuffs from various local tradesmen and farmers. In addition to the payment of $6,000 to "Z. N. Russell on act. of timber" on September 2 the firm of Camfield & Melony was paid $188.16 for "40 sticks of hemlock" that same day. On September 7 Moses Brink was paid $157.50 for "21 oak." Ed. Swanton was paid $3 on September 22 for trotters and tools. In late October and early November, castings were

17. "Ledger. John A. Roebling. Aquaduct. Monongahela Br.," Roebling Collection, Box 7, Rutgers, The State University.

received from Rodman & Co. and No. 14 wire from Rodenbough Stewart & Co.[18]

Operations at the site of the Delaware Aqueduct progressed rapidly during the fall of 1847. Writing from the "Deleware Aquaduct" on September 25, Roebling informed Lord:

> Mr. Russell wishes a draft of $1500--on act. His whole bill, when delivered, will amount to $8452 without the extra charge for enlarging the trunk posts. As I shall have need of the whole amount of $5000 which you have authorized me to draw, on my return from the West, I request you to pay to Mr. Russell $1500--on my account.[19]

Later on December 20 Roebling informed Lord that he had been invited by the Niagara Bridge Company to present plans for a suspension bridge over Niagara Gorge on November 1. In all, he would be away from the Delaware Aqueduct site for almost two weeks. He noted that the "laying of the anchor masonry will not be delayed by my absence. I will leave such instructions, that nothing can go wrong."[20]

The work on the aqueduct was described by Charles M. Dupuy, one of Lord's assistant engineers, in two letters to Lord on October 31 and November 17. Having arrived at the aqueduct on October 30, Dupuy informed the chief engineer that he intended to run "the line of new canal on the N. Y. side tomorrow, and hope to have it ready for your inspection." Relative to the aqueduct itself, he observed:

> The Pier on the Penna. side is completed. The middle Pier will be finished I think in about the 10th of the month, and the one on NY side before the 20th. They are getting

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18. "Cash Book. John A. Roebling. Deleware & Hudson Aquaducts. July 1847 to June 1850," Roebling Collection, Box 16, Rensselaer Polytechnic Institute.

19. Roebling to Lord, September 25, 1847, Lord Collection, Minisink Valley Historical Society.

20. Ibid., October 20, 1847, Lord Collection, Minisink Valley Historical Society.

along tolerably well with the anchorage on the NY side. I think there is no doubt but that the Delaware Aquaduct will be completed so far as to allow Roebling to put on his wires this winter--but it will take every moment of time.

McClellan Smith and Guffy were seriously hurt by a blast, though not dangerously.[21]

Several weeks later on November 17 Dupuy sent another progress report to Lord relative to work being performed on the Delaware Aqueduct. His comments were:

> As they were hoisting one of the largest Pyramid stone on the Pier next to NY side--the crane gave way--and as a consequence the stone fell and was broken. It being very doubtful whether Mr. Dupuy could get out one of these large stone and have it delivered before the close of navigation I have concluded to lay the bottom course of this pyramid of two stone, taking for that purpose one of the smallest stone designed for the abutment, and the remains of the broken stone. I have dispatched a letter to Mr. Depuy [sic] to provide one stone of the smallest size, for the abutment, to supply the place of the one that we shall use. . . .
>
> Mr. Roebling has returned without being successful in his Niagara Bridge. . . .
>
> Mr. Watson is getting on as well as usual with his stone work. I now very much doubt whether the anchorage walls will be finished until near the end of December. The abutments will in all probability be completed by the close of this month. This work is costing a great deal of money--more I fear than it should. Yet I do not see that I can change it. I have pushed Mr. Watson at various [times] so hard, that a short time ago he said to me "If he were to be discharged tomorrow he could not make it go faster than it is." I was convinced by this that he was sincere. Observation only proved to me that he is not suited to take charge of a work of so extensive a character. . . . This work however must soon draw to a close, and then I do not know of any thing of this character in the companies business which will draw together such a man of labor so difficult to place under the right management as this.

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21. Dupuy to Lord, October 31, 1847, Lord Collection, Minisink Valley Historical Society.

About 45 tons of the cable wire has come. About 55 tons is yet to come this fall. It is shiped [sic] and is expected here soon. Some of the anchorage bars for the last course of stone are yet behind, but Mr. Roebling designs to have them sent by R. R. if they do not arrive before the close of navigation. He designs to commence putting up his cables as soon as we give him the work.[22]

On November 20, 1847, Roebling submitted to Lord an estimate of material delivered and work accomplished on the two Delaware and Hudson Canal aqueducts. The estimate read:

Russels Timber	$8,500	
Cawpfield	190	
Moses Brink	162	
Kimble	554	
Timber on ground	9,406	$9,500
Carpenter work done	1,000	1,000
Castings all delivered		
P. & C. Shavers small castings	800	800
Rodman & Co. large castings	2,356	2,400
Anchor bars delivered and shipped	4,800	
Drilling, turning & fitting	800	5,600
Iron on hand	1,180	
Smithing done &	400	2,000
Wire delivered 170,000 lbs. 8 cs.		13,600
Machinery on hand		600
Anchorage		500
Sundries, materials & Shanties		1,500
		$37,500[23]

The payments which had been advanced to Roebling as of November 20 amounted to $18,096.16. On December 1 he would have additional payments to make amounting to $6,000 or $7,000.[24]

22. Ibid., November 17, 1847, Lord Collection, Minisink Valley Historical Society.

23. "Suspension Aquaducts . . . Febr. 1847," Roebling Collection, Box 4, Rutgers, The State University.

24. Roebling to Lord, November 20, 1847, Lord Collection, Minisink Valley Historical Society.

Work on the Delaware and Lackawaxen aqueducts continued during the winter of 1847-48. On January 21, 1848, Lord wrote to John Wurts:

> The masonry of the Delaware aqueduct is completed and ready for the superstructure which Mr. Rockberg [sic] is now erecting; the stone and materials are mainly provided for the Lackawaxen aqueduct, which we contemplate having completed ready for the superstructure early the ensuing spring. All the works connected with those aqueducts (as well as the aqueducts,) are being built in a substantial manner and suitable for the proposed enlarged canal. We contemplate getting this work ready for use during the fall of 1848.[25]

That same day Dupuy reported to Lord relative to work underway in the vicinity of the mouth of the Lackawaxen. He observed that:

> Things go on as usual here. Today Watson commences at the Lackawaxen abutment. Johnson will be very much troubled with water in the lock excavation. I think it altogether best to put in one of the screw pumps. All we shall have to do is to remove the old frame work used at the Del. aqueduct to the place required. If they can get rid of water I see no reason why they can not lay foundation timbers towards the close of next week.[26]

Work on the Delaware and Lackawaxen aqueducts was largely completed by late 1848 although some minor finishing touches were performed during the early months of 1849. High floods along the Delaware during the spring of 1848 may have hampered operations.[27] There is no known correspondence relating to the construction operations during this period. Some information can be extracted from Roebling's ledgers, cash books, and check rolls, although many entries can not be determined with accuracy as to the reason for the expenditure, the

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25. Lord to Wurts, January 21, 1848, printed in <u>Delaware & Hudson Canal Co. against Penn. Coal Co., Exhibits</u>, [1858], Exhibit C, XXV.

26. Dupuy to Lord, January 21, 1848, Lord Collection, Minisink Valley Historical Society.

27. <u>Annual Report of the Delaware and Hudson Canal Company, 1848</u>, pp. 3-4.

service performed, or the exact nature or description of the material or supplies being purchased. While a definitive account of the post-November 20, 1847, construction period cannot be determined, some data on this period may be found in the following manuscript materials: "Ledger of John A. Roebling, November 1848, Delaware Aquaduct, Lackawaxen Aquaduct," Roebling Collection, Box 7, Rutgers, The State University; "Cash Book, John A. Roebling, Deleware & Hudson Aquaducts, July 1847 to June 1850," Roebling Collection, Box 16, Rensselaer Polytechnic Institute; and "Payments on Account of Check Rolls, Deleware & Hudson Aquaducts" and "Check Roll, D & H Aquaducts," Roebling Collection, Box 10, Folder 7, Rensselaer Polytechnic Institute.

Throughout the period of construction Roebling continued to make calculations and write comments in his notebooks about various facets of the operations. Although most of these entries are undated, they do contribute to an understanding of the techniques employed by Roebling in erecting the two suspension aqueducts. In his "Suspension Aquaducts . . . Febr. 1847" Roebling wrote the following observations and calculations for the Delaware Aqueduct:

> The suspension rods at the abutments should not be slackened, as the forward movement of the saddles will slacken them sufficient. They should rather be kept tight. Those at the Piers should be slackened, to prevent their drawing up of the woodwork in winter, also to lower the Centre & throw weight upon the piers.
>
> . . . .
>
> The length of suspenders on Deleware Aquaduct were calculated, an extra allowance of length made (0.30) for the first rod, diminishing to No. 7--and the same proportion of length deducted from the center rods. Experience proved, that these allowances and deductions were too great & should not have been made. The suspenders next the piers proved too long, by 3 inches and those at the Center were barely long enough. The length as calculated would have been most correct.

Roebling also noted the calculations for the cables as built:

	Ist Span (Penna. shore)	2nd Span	3rd Span	4th Span
Length of Span	141' 9"	131'	131'	131' 6-3/8"
Bottom of saddle above canal bottom	12' 7"	12' 7"	12' 7"	12' 7"
Point of intersection	12' 10-1/2"	12' 10-1/2"	12' 10-1/2"	12' 10-1/2"
Lower side of cable at bottom	5-1/2"	1' 3-1/2"	1' 3-1/2"	1' 6"
Deflection of cable	12' 5"	11' 7"	11' 7"	1' 6"
Camber	7"	4-1/2"	4-1/2"	7" [28]

28. "Suspension Aquaducts . . . Febr. 1847," Roebling Collection, Box 4, Rutgers, The State University.

A second notebook of Roebling's entitled "Wire Cables & Machinery, August 1848, Important General Remarks, Construction of Deleware A. Cables, Niagara Bridge" includes considerable data on the construction of the cable suspension system for the Delaware Aqueduct. Relative to the cables, Roebling wrote:

> No. 1 & 2 strand contain 270 wire, each measured from 9 1/8" circ. (solid & compact) to 9 3/4" (rather loose). The Center consists of 10 courses in Shoe & counts 330 wire, it was made 2" longer than No. 1 & 2, the consequence was, that at both ends segments (malleable iron brom 1/4" to 1" thick) of 1 1/2" had to be introduced, which proves, that it is shorter than No. 1 & 2. The cause of this is owing to the great flatness and width of the Saddles. It appears, that the shape of the Pittsburgh saddles is much preferable, little or none wider than the diameter of the Cables. No. 3 was so suspended, that the distance a b did not exceed 5".
>
> The outside threads were wrapped at intervals of 15" with No. 14 wire, passed around twice and twisted outside, as shown at c c c, so that they can be removed, when the large wrapping is put on. The center was wrapped every 8" with 4 turns of No. 22, which was left on.
>
> Three temporary wrappings, which are put on, while the wire are exposed to the full strand, are very necessary, to keep the wires in their position and to adjust the strands, they also assist the wrapping. The english wire was very hard and elastic and requires confinement. . . .
>
> The first span of the Deleware is 142' from C [enter]--C [enter], and 3 others are 131' wide, total dis[tance] from C-C of abutment 535' 5". The Guideline measured 575' 2", suspended in one sweep with a deflection of 15'. Weight of 575' of No. 9 wire: 17,777 = 33.48 lb. [or] . . . 160.62 lb. tension.
>
> This tension is enough for laying No. 9 wire, but not too much, it might be increased to 200 lb., if the nippers were made larger, to hold with more leverage. . . .
>
> Great attention is necessary in adjusting the wires, when the temperature changes from the wind or sun, the wires are constantly rising & falling, this is very important in large spaces. The threads, as the sum is changing, is constantly turning. A cloudy dark and sunny clear day are the best. Stormy winter weather very objectionable, moving the wires & traveling wheels, choose the good season, whenever it can be done.

> After a wire is run out, it requires some little time, before its temperature is equalised to that of the strands. . . .
>
> It is very important that the wire should be drawn of a uniform thickness, the length of each strand as well, as the different strands. The irregular thickness of the No. 9 english caused the curves of the various wires to differ very materially. . . .
>
> It is also important, that the skeins should be as long as possible, to reduce the labor and the number of splices. Some of the english strands (good quality/furnished by a celebrated cart wire factory weighed 40 lb. No. 9.) The mixing of Spanish brown with the oil does well. Also the wire, immediately on receiving it, & before it gets hard & rusty, should be oiled, the oil kept warm, in which state it runs off the skeins easier and cleaner.
>
> The tension of one wire was ascertained by weight to be 153 lb. deflection about 15 1/2 to 16', which agrees well with the calculations. Adding 7 lb., caused the wire to rise about 6 inches, 7 lb. more would raise about 6" more. The greatest difference in the deflection of the different wires does not exceed 2 at most 3 inches, which would be equivalent to 2 to 3 lb. tension.

Roebling also noted some observations relative to the saddles on the Delaware Aqueduct. The saddles were

> 11" wide . . . entirely too much--9" for a 8 1/2" cable would have been about right. . . . The roundness of the strands should be preserved through the saddle. If the latter is too wide, the strands flatten too much, the wires spread and cause unequal tension. . . .

To adjust the length of strands Roebling used

> segments of malleable cast iron. These were to be from 1/8" to 1" thick or say 1/8", 1/4", 1/2", 1"--they file well, are easily introduced & removed, and will adjust very accurately. This mode together with long shoes of no less than 10" wide inside, appears much better, than the usual mode of introducing wedges, at any rate it answers well, where the Aquaduct plan is applied, of connecting 7 strand with one anchor chain.

Roebling devoted considerable attention to the matter of "adjustments of the 7 strands" on the Delaware Aqueduct. He noted:

> The temporary wrapping of the strands, from 15 to 18 inches, has proved necessary and useful, it is then easy to adjust the strands properly. The strands for a cable of 8 1/2"

diameter . . . should be so suspended, that they will gauge 8 1/2" in. depth, they must therefore be spread horizontally. The Centres of the strands should form the right deflection. Before the wrapping is commenced, it is useful to put some temporary bands every 5 feet around the whole, to keep the strands in their relative position. When suspending the strands, they may be gauged with a fork at the Centre and different other points, if there is a chance.

The rollers of the carriage should be deep' and wide so that they fit the cable nearly, if they are too flat, they have a tendency to press upon the upper two strands alone and derange their relative position . . . the plan of carriage, adopted for the D. A. proved much better, than the arrangement on the Allegheny.

In the 2d span of the D. A. the upper 2 strands were pressed down by the rollers being too flat, when wrapping from the pier towards the Centre, the consequence was, that these sunk between the outside strand, and rose in the Centre of the span, where the lower strands got quite slack. This shows the necessity of deep grooved rollers, which will press against the sides as well as top.

The 7 strands should be suspended in 3 strata, which in thickness together occupy a depth, equal to the diameter of the cable, so that the deflection of the mass of the strands will not be changed. . . . The D. strands in the 2 & 3 span were not enough spread, and occupied too deep a stratum.

It is very important and necessary to put strong temporary bands around the 7 strands, one every 5 ft., before commencing wrapping. These will keep them in their position; without them, the 2 top strands will be pressed down by the rollers of the Carriage, which will cause to rise in the other half span. This will be prevented by these Bands. It is not necessary to untie the strands, while putting on these temporary bands around the whole. The screw clamps should be used to that effect, which act very powerful. . . .

Screw squeezers were used by Roebling to compress the Delaware Aqueduct cables. They were

much more powerful, than tongues, and more convenient too. They should be cast . . . Ring 1" x 2". They are put on so, that a T forms a horizontal line, the strands being spread out in this direction. By means of these clamps, a perfectly solid wrapping may be made. There should be 2 clamps for every machine. They will save much pounding &c.[29]

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29. "Wire Cables & Machinery, August 1848, Important General Remarks, Construction of Deleware A. Cables, Niagara Bridge," Roebling Collection, Box 4, Rutgers, The State University.

Roebling also described the operation of the wrapping machines used at the Delaware Aqueduct. The machines

> proved a quarter inch too wide, or the cable too small. Still the barrel would move with great difficulty, without making a very compact wrapping. The wide end of the barrel should be at least 1/2 inch, and even wider than the end at the flyer. Weights were suspended over a snatch block in advance of the machine to propel it, this worked very well. Commenced at the pier and wrapped towards the Centre. In order to make the cable solid and compact, it is necessary, that the tongues for squeezing should be very strong (screw clamps are much better), those on the D. A. and Allegheny A. were too weak and light. The progress of the machine can be regulated by the weight. The barrel of the D. machines are too long, and the reels too large. Those on the Allegheny Aquaduct are much better proportioned. The construction of the flyer, with a steel ring, screwed on, is good. The large end of the D barrel is only 1/4 inch wider, than the small end, it should be 1/2" for such a long barrel.[30]

In a notebook entitled "Notes on Suspension Bridges by John A. Roebling" he made a number of comments and observations about his bridge projects over a 10-year period beginning about 1846. The notebook contains considerable material on the Delaware Aqueduct, all of which was written after the completion of the structure. The notations were organized under the following topics:

1. Oiling Wire

   160,000 lb. No. 9 wire oiled once on the Deleware Aquaduct with 2 1/2 bbls. linseed oil, well boiled and mixed with some spanish Brown, no litherage. Kept the oil warm all the time and stuped the skeins in a trough, containing the warm oil. This mode prevents sticking. Warm oil is better than cold.

2. Measurements of Cables

   180 lb. No. 9 Deleware Aquaduct measure 2233' . . . = 17,177 ft. Each cable of 8 1/4" d without wr. was made in 7 strands. Length of strands 573', made in one sweep with

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30. Ibid.

15' deflection. Tension of each wire = 160 lb., tension of 300 wires (1 strand) = 48,000 lb. The nippers held the wires, when cleaned of the oil, well, without slipping. Weight of 1 strand = 10,050 lb.

Strength of No. 9 Wire . . . which remained suspended one night and broke towards morning . . . broke with 2088 lb. . . . .

No. 9 Wire. Circumference without wr. 2' 1 3/4", 2' 1 3/4", 2' 2", 2' 2" or 8 1/4" diameter.

Circumf. with wrapping 26 1/4" or 8.36" diameter, intended to be 8 1/2". Circumf. of a strand of 300 W--9.3".

2 first strands contain together	(270 W
	(270
3d or Centre, 10 courses	320
4th	320
5th	320
6th	325
7	325
Total Number of Wires	2150 W

Weight of both cables without wrapping No. 9 wire--141,000 lb.
Total length of each cable 576 feet
Weight pr. foot without Wr. 122.74 lb.
1 lb. of No. 9 wire measures 17.516 ft. according to weight of cables. The english wire is a little larger than the N. York wire. . . .

3. Caulking

The Deleware Trunk 545 ft. long without extensions, double course, both caulked with a large single thread 6 1/2 ft high, 40,000 ft. of seams in all consumed.

1000 lb. cotton	9 1/2 c	$ 95.00
350	8 1/2	29.75
100 oakum	6 3/4	6.75
8 bbls. pitch	9 sh	9.00
3 bbls. tar	18 sh	6.75
Freight		8.00
		$155.25
144 days work	2.00	288.00
Spinning and pitching		40.00
Total		$483.25

4. Estimate of Spikes

29 casks (100 lb.)	4 1/2"	lut spikes
28 casks	5 1/2"	lut spikes
22 casks	6"	lut spikes
4 casks	12 penny N. for 2 c:	towpath
83 casks in all		

5. Camber

Camber of 1st span of	141' 9" was	8"
2d span & 3d span =	131'	6"
4th span	131' 5"	8"

The first span, although the saddles only moved 1/2", but owing no doubt to the greater deflection & great heat of Summer has settled nearly down to a level. The other 3 spans have settled only about 3 inches.[31]

The Delaware and Lackawaxen aqueducts were completed by January 1849. The actual cost of the two structures was $51,800, compared to the contract price of $60,400, thus providing Roebling with a profit of $8,600. The Delaware Aqueduct (contract price-- $41,750) cost $77 per foot and the Lackawaxen (contract price-- $18,650) $81.[32]

A notation in Roebling's notebook entitled "Suspension Aquaducts . . . Febr. 1847" summarized the cost of labor on the two aqueducts to January 1, 1849. The figures cited were:

Labor & Wire Work, including labor at raising, screw cutting		$1,950
Smithing (no screw cutting)		1,200
Carpenter work	$3,384	
Jonathan Rhule	1,100	
		4,500
Total wages (caulking not inc.)		$7,650

Total quantity of timber framed and put up, not incl. anchorage is 520,000 ft. B. M. which make the carpenter work cost at the rate of 4500:520 = $8.65 pr. 1000 pr. B. M. It is therefore safe to estimate at the rate of $1000 pr 1000. The finishing of both works may cost $300 more, which will make it over $9.00 p 1000. . . .[33]

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31. "Notes on Suspension Bridges by John A. Roebling," Roebling Collection, Box 17, Rensselaer Polytechnic Institute.

32. Ibid.

33. "Suspension Aqueducts . . . Febr. 1847," Roebling Collection, Box 4, Rutgers, The State University.

On January 6, 1849, Lord informed John Wurts that the Delaware and Lackawaxen aqueducts and related improvements were completed. The two aqueducts

> with the new piece of canal and three large locks connected with them, will be brought into use at the commencement of navigation next spring, and thereby the objections of boatmen to crossing the river during the ensuing season, as well as the delay occasioned by freshets at that place, will be removed. The work for a general enlargement of the canal has been prosecuted with considerable energy during the past year, and about 3,200 men, including the common laborers and mechanics, are employed on that work at this time. . . .[34]

After the aqueducts were completed Roebling provided a description of the two structures to the American Railroad Journal for publication on January 13, 1849. The article read:

> The Delaware river is now crowded in a pool at the mouth of the Lackawaxen. To avoid the frequent delays, caused by high water and rafting, a total change of location was concluded on by R. E. Lord, Esq., principal engineer in charge of the canal. This change rendered the construction of two aquaducts over the Lackawaxen and Delaware rivers necessary. After an examination of the Pittsburgh suspension aquaduct, Mr. Lord advised the company, to adopt the same plan, and to accept my proposal for the erection of the super structure, the masonry to be done by the company. The two works are now completed and ready for the operating of navigation next spring.
>
> The following exhibits some of the dimensions of the Delaware aquaduct.

Number of spans, varying from 132 to 142 ft.	4
Width of bottom of trunk, - -	17 ft. 6 in.
" " trunk on top, - -	20
Depth, - - - - - -	9
Depth of water, - - - -	6
Weight of water is 142 ft. span in tons of 2000 lbs.	481 tons.
Tension of cables resulting from this weight	708 "
Diameter of each of the two suspension cables, - - - - -	8 1/2 inch
Number of strands composing a cable,	7

34. Lord to John Wurts, January 6, 1849, printed in Delaware & Hudson Canal Co. against Penn. Coal Co., Exhibits, Exhibit D, xxxi.

Number of wires in each strand, -	307	
" " in one cable, -	2150	
" " in both - -	4300	
Number of feet of wire, weighing 1 lb	175	
Weight of one lineal foot of cable and wrapping - - - -	130	lbs.
Length of each cable and anchor chains	664	ft.
Average strength of one wire -	1800	lbs.
Ultimate strength of both cables -	3870	tons.

> The wire cables do not extend below ground, but connect with anchor chains, the cross sections of which exceeds that of the wire fifty per cent; the strength of wire being 90,000 lbs. per superficial inch, while the chains will not bear over 60,000 lbs.
>
> The trunk of this aquaduct is lined with a towpath of 6 feet wide on each side.
>
> The Lackawaxen aquaduct, forms two spans of 114 feet each, suspended to two cables of seven inches diameter, same size as those at the Pittsburgh aquaduct.[35]

In a short editorial following this article D. K. Minor, publisher of the <u>American Railroad Journal</u> and a friend of Roebling, commented on the significance of the Delaware and Lackawaxen aqueducts. According to Minor:

> Mr. Roebling's work, both on a suspension aqueduct and a suspension bridge--has been thoroughly tested at Pittsburgh, for several years with heavy loads and, as far as we have heard, with entire success; and, from what we hear in relation to those which he has just finished for the Delaware and Hudson canal company, of which we give above a partial description, he will lose none of his well earned reputation, as we are quite sure they will be found equal to the work required of them.[36]

A "Statement of Acct. of Delaware Aqueduct" was found in the Lord Collection at the Minisink Valley Historical Society. The statement

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35. John A. Roebling, "Suspension Aquaduct on the Delaware and Hudson Canal," <u>American Railroad Journal</u>, XXII (January 13, 1849), 21.

36. <u>Ibid</u>.

includes entries from May 12, 1846, to January 17, 1849. The total charges for the structure amounted to $180,541.46.[37]

In March 1849 the canal board of managers reported that "the aqueducts across the Delaware and Lackawaxen Rivers have been completed, thereby precluding any further delays from freshets at that point." The managers observed that they perceived "no obstacle to interfere with the transportation of 500,000 tons of coal over the Canal during the present season."[38]

The aqueducts were brought into use on April 26, 1849, when the canal was opened for the season. Distinguished engineers from many parts of the United States, as well as a large crowd, were on hand when the aqueducts were filled with water and the first boat sent through. Apprehension on the part of some that the weight of water and a loaded boat were too heavy for the wire cable suspension system to sustain proved unfounded.[39]

On July 7, 1849, after the aqueducts had been in service for several months, another description of the structures appeared in the American Railroad Journal:

> The Wire Suspension Aqueducts, over the Delaware and the Lackawaxen rivers, which were commenced in 1846 and recently completed on the Delaware and Hudson Canal, are now opened for the passage of boats. These works have been erected for the purpose of avoiding the delay, formerly experienced in crossing the Delaware river by means of a dam, and will materially improve the navigation. They are constructed on the plan of the Pittsburgh Suspension Aqueduct,

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37. "Statement of Acct. of Delaware Aqueduct," Lord Collection, Minisink Valley Historical Society. A copy of this statement may be seen in Appendix F.

38. Annual Report of the Delaware and Hudson Canal Company, 1848, pp. 5-6.

39. Wakefield, Coal Boats to Tidewater, p. 84; LeRoy, Delaware & Hudson Canal, p. 51; The Hancock Herald, June 15, 1933.

a structure which has proved eminently successful and was the first of its kind in the world, designed and executed by John A. Roebling, Civil Engineer of the city of Pittsburg. After an examination of the work at Pittsburg by Mr. R. F. Lord, Chief Engineer of the Delaware and Hudson Canal, a contract was entered into with Mr. Roebling for the erection of the superstructure of the Delaware and Lackawaxen Aqueducts.

The trunks which hold the water are composed of timber and plank, well joined and caulked, and suspended from two wire cables, one on each side. The cables rest in heavy cast iron saddles which are placed on the top of small stone towers of 4 by 6 ft. base rising 4 feet above the towpath. The trunks are wide enough for two boats of the present capacity to pass, and on each side side [sic] of each trunk is a towpath. The towers are each composed of 3 blocks of a white quartz pudding stone, of great hardness and durability, obtained from the quarries in Ulster county, N. Y. The masonry of the piers and abutments, which support the little towers, has been executed in the most substantial manner, of a durable and compact gray wacke, which constitutes the principal formation of the valley of the upper Delaware. The beds of the facestone are all cut, the backing is large and well bounded, and the whole laid in hydraulic cement. Nothing has been spared to insure the safety of the foundations, and, by the construction of good ice breakers, to guard the piers against the heavy floods and ice, which in this river prove sometimes very violent and destructive.

The cables are each made in one length across the river from abutment to abutment, and connected at their ends with anchor chains, manufactured of solid wrought iron, in bars of iron 5 feet to 10 feet long and 5 to 6 inches wide, by 1 1/4 inch thick.--The lower end of each chain is secured to a heavy cast iron anchor plate of 6 ft. square, on which rests a large body of masonry, whose weight resists the strain of the chain and cable. As the cables are protected against oxidation by paint and a copious varnish, and are closely encased by a tight wire wrapping, which gives them the appearance of solid cylinders, they may be considered indestructible. The woodwork is subject to decay, but will last longer in these works than in common timber structures, and can be renewed at any time.

The following table exhibits the principal dimensions and quantities of the Delaware Aqueduct:

Hydraulic cement masonry in Abutments, Piers and Anchorage	7,688	C. yds.
Length of Aqueduct with extensions	600	ft.
Number of Spans	4	
Length of Spans varies from 131 to	142	ft.
Width of Trunk at water line	19	
Depth of water	6	ft. 6 in.
Weight of water between abutments	1,950	tons.
Weight of water in one Span	487	1/2
Diameter of wire cables	8	1/2 in.
Length of wire weighing 1 lb	17	1/2 ft.
Number of wire in each cable	2,150	
Total weight of cables and anchor chains	490,000	lbs.
Ultimate strength of each cable	1,900	tons.[40]

After the aqueducts had been in operation for a full operating season the canal managers reported on their significance to the canal's operation. Despite a long and severe winter in 1848-49 all of the canal improvements had been ready when the canal opened for navigation on April 26. The operating season lasted until December 6 "with less interruption than usual, furnishing conclusive evidence in favor of the strength and permanence of the new work." The "two Wire Suspension Aqueducts over the Delaware and Lackawaxen Rivers" were "a part of the new work brought into use" and were "all that was expected or can be desired of such structures, and [were] a great facility to the navigation."[41]

About the same time Lord reported to John Wurts on the performance of the two aqueducts during their first season of operation. The structures had

> proved valuable improvements to the navigation, being also substantial and permanent structures, sustaining all that has been claimed for the utility of wire suspension aqueducts. There have been nine days during the past season that boats could not have crossed the Delaware Pond on the former plan of crossing during freshets in the river. With the aqueduct the

40. "Wire Suspension Bridge," American Railroad Journal, XXII (July 7, 1849), 421.

41. Annual Report of the Delaware and Hudson Canal Company, 1849, p. 3.

navigation has not been interrupted at that point during the season.[42]

The construction of the aqueducts necessitated the construction of three new locks (Nos. 70, 71, and 72) on the New York side of the Delaware to bring the boats to the new high level, but at the same time Locks Nos. 1, 2, and 3 along the Lackawaxen were eliminated. The dam across the Delaware was retained and heightened to 16 feet to increase the effectiveness of the slack water area for canal feeder purposes. The old bed of the canal between the guard lock and the Delaware Aqueduct was used for the feeder.[43]

While Roebling was working on the Delaware and Lackawaxen aqueducts he was asked to submit proposals for the construction of wire cable suspension aqueducts to carry the Delaware and Hudson Canal over the Neversink River at Cuddebackville and Rondout Creek at High Falls. On December 28, 1847, Roebling submitted three propositions to Lord: one for a single-span aqueduct at High Falls, one for a 170-foot, single-span aqueduct with cables 9-5/8 inches in diameter over the Neversink, and one for a 180-foot, two-span structure with cables of 6-3/4 inches over the Neversink.[44]

Roebling prepared more detailed plans and estimates for the two aqueducts in October 1848 by which time the board of managers had

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42. Lord to John Wurts, February 6, 1850, printed in Delaware & Hudson Canal Co. against Penn. Coal Co., Exhibits, Exhibit B, xviii.

43. LeRoy, Delaware & Hudson Canal, p. 51, and Wakefield, Coal Boats to Tidewater, p. 84. The dam was "brushed" and "graveled" every spring to make it less susceptible to leaks. Brackets were also placed on the crest of the dam to increase the area of the slackwater. The feeder was dammed up and a significant portion of the Delaware and Hudson Canal prism along the Delaware was filled in during construction of Highway 97 in 1933-34. Personal interviews with Carl A. Draxler, Minisink Ford, New York, May 3, 1983, and Arthur H. and Annabel Haupt, Lackawaxen, Pennsylvania, May 4, 1983.

44. "Suspension Aqueducts . . . Febr. 1847," Roebling Collection, Box 4, Rutgers, The State University.

chosen a single-span aqueduct over the Neversink. On November 11 he submitted the following proposal to Lord while overseeing the operations at the Delaware Aqueduct:

> I propose to construct the Never Sink Suspension Aquaduct in one single span of 160 ft. in the clear or 170 ft. from center to center of abutment for the sum of Twenty Four Thousand Nine Hundred (24,900) dollars. My work to include all the iron, wire & wood work; the trunk to be of the same dimensions as the one of the Delew. Aquaduct and to be supported by two Wire Cables of 9 1/2 (nine & one half) inch diameter each, anchored at both ends to solid chains & oak timber foundations, similar to the Del. plan. Extensions to be added to both ends of trunk & of same dimensions as on the Deleware A.
>
> I also propose to construct the High Falls Suspension Aquaduct in one single span of 130 ft. in the clear or 140 ft. from center to center of abt. for the sum of Twenty Thousand Four Hundred (20,400) dollars, including all the iron, wire & wood work; the trunk to be of the same dimensions as on the Del. A., and to be supported by two wire cables of eight and one half inch diameter each, connected at both ends with solid anchor chains, which are to be secured in the solid rock; the trunk to be extended in same way as above.
>
> Both works to be completed within the year 1849, provided the masonry & excavations, which are to be done by your Company, will be prosecuted with such speed, that my operations can be commenced early next spring and continued during the season without interruption.
>
> It shall be understood, that the above works are to be constructed on the same general plan and in the same manner as the Del. Susp. A., and that the specification, which was attached to my contract for the last work, shall also be binding for the above works.[45]

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45. Roebling to Lord, November 11, 1848, "Never Sink Aquaduct. High Falls. Oct. 1848. John A. Roebling," Roebling Collection, Box 4, Rutgers, The State University. The detailed estimates Roebling drew up on October 25 before submitting this proposal may be seen in Appendixes G and H.

The canal company managers authorized construction of the Neversink and High Falls aqueducts on December 2, 1848, and Roebling was informed of this decision by letter on December 9.[46]

The Neversink Aqueduct was of importance because the largest cables (9-1/2 inches in diameter) yet constructed were used. Roebling's own comment on the importance of the Neversink is contained in the concluding paragraph of a letter to the American Railroad Journal printed on January 13, 1849:

> I have contracted with the company, for two more aquaducts, one over the Roundout river, the other over the Sink river, of 170 feet span, requiring cables of 9 1/2 inches diameter, large enough for the support of a suspension bridge over the Niagara river, at the site in contemplation below the falls, of 750 feet span.[47]

The two aqueducts were completed early in 1851 and placed in service during the boating season that year. Roebling wrote to Charles Swan from Cuddebackville on January 14, 1851, "We shall commence screwing up to morrow and get through this week. Perhaps I may leave here next Sunday or Monday."[48] Lord informed John Wurts on February 6, 1851, that the Neversink and High Falls aqueducts were "nearly completed in a substantial manner."[49] Entries in Roebling's ledger for

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46. Roebling to John Wurtz, December 16, 1848, "Never Sink Aquaduct. High Falls. Oct. 1848. John A. Robeling," Roebling Collection, Box 4, Rutgers, The State University, and Malcolm A. Booth, "Roebling's Sixth Bridge, 'Neversink,'" Journal of the Rutgers University Library, XXX (December, 1966), 16-17.

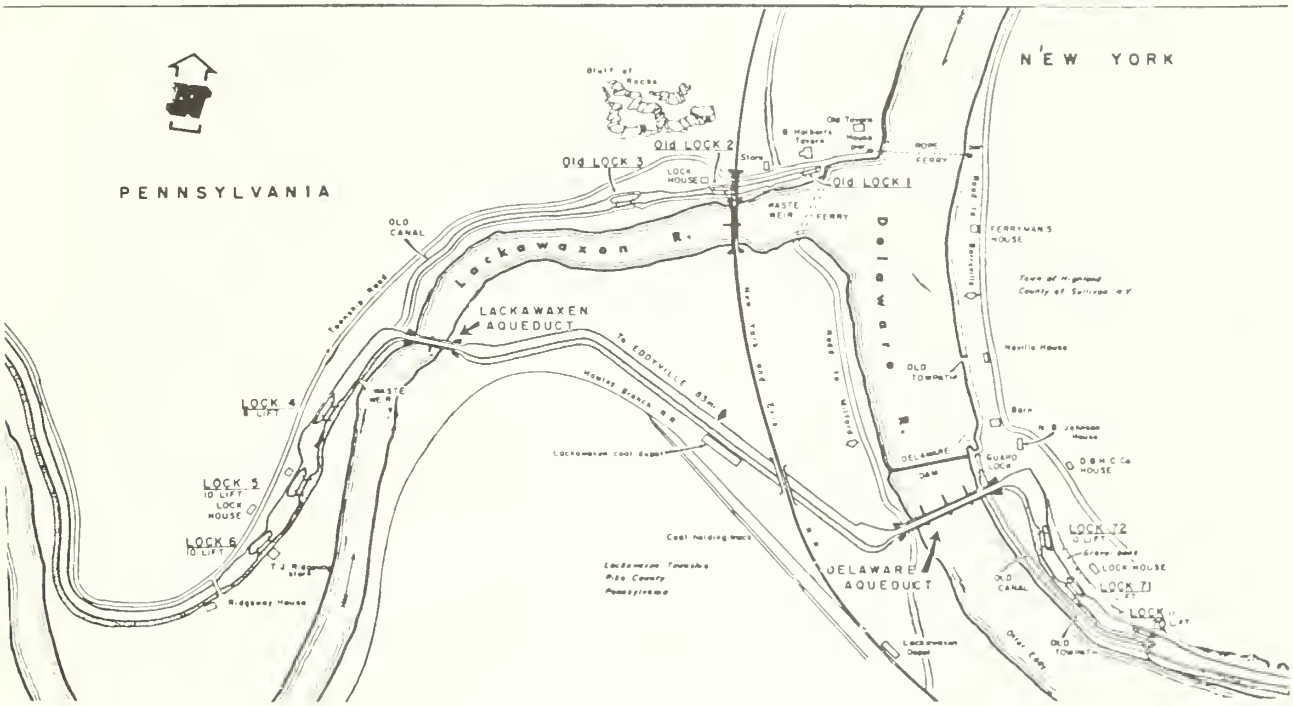
47. Roebling, "Suspension Aquaduct on the Delaware and Hudson Canal," 21.

48. Roebling to Swan, January 14, 1851, Letters, John A. Roebling to Charles Swan, 1849-65, Roebling Collection, Box 2, Rutgers, The State University.

49. Lord to John Wurts, February 6, 1850, printed in Delaware & Hudson Canal Co. against Penn. Coal Co., Exhibits, Exhibit B, xxi.

the period indicate that he received final payment on his contract for the two aqueducts on May 16, 1851. All told he had been paid $45,793.92 for the two structures.[50]

50. "Ledger of John A. Roebling, November 1848. . . ," Roebling Collection, Box 7, Rutgers, The State University. More data on the construction of the Neversink and High Falls aqueducts may be found in Booth, "Delaware and Hudson Canal," pp. 55-64, and Booth, "Roebling's Sixth Bridge," 12-20.



Wakefield, Coal Boats to Tidewater, p. 83.

CHAPTER FIVE
ACCOMPLISHMENTS AND SIGNIFICANCE OF JOHN A. ROEBLING'S CONTRIBUTIONS TO SUSPENSION BRIDGE TECHNOLOGY

A. CAREER AND ACCOMPLISHMENTS OF ROEBLING UP TO CONSTRUCTION OF DELAWARE AND HUDSON CANAL AQUEDUCTS

John Augustus Roebling, born in Muhlhausen, Thuringia, Germany, on June 12, 1806, attended the Muhlhausen public schools and the city Gymnasium before entering the Royal Polytechnic Institute in Berlin. There his course included architecture, engineering, bridge construction, hydraulics, languages, and philosophy. At the age of 20 he received a degree in civil engineering, and for the next three years he worked for the Prussian government on road building in Westphalia. His primary interest was bridge construction, particularly that of suspension bridges. He made a special study of a chain suspension bridge over the Regnitz River at Bamberg in Bavaria, and subsequently presented his study as a thesis for his state examination.

His creative ideas and inventiveness hampered by red tape and official inertia, Roebling, with his brother Karl, left Muhlhausen for Bremen in the spring of 1831 and later sailed for Philadelphia, reaching that city on August 6. After several weeks the brothers left for Pittsburgh, traveling mainly by the Pennsylvania Main Line Canal system. They purchased 7,000 acres of land in Butler County, about 25 miles from Pittsburgh, and settled in company with a small group of German colonists. The small hamlet, first known as Germania and afterwards as Saxonburg, served as a focal point for their efforts to attract German emigrants to their agricultural experiment.

The agricultural experiment proved to be unsuccessful and thus in 1837 Roebling went to Harrisburg and applied for employment as a state engineer and became a naturalized U. S. citizen. After serving as an assistant engineer on the slack water navigation of the Beaver River, he

was engaged on the Sandy and Beaver Canal, a work intended to connect Lake Erie with the Ohio River but never completed, and on the Pennsylvania Main Line where he located a feeder near Freeport on the upper Allegheny. Then he served as a Pennsylvania state engineer for three years, surveying and locating three lines of railway across the Allegheny Mountains between Harrisburg and Pittsburgh, the road ultimately being built by the Pennsylvania Central Railway Company.[1]

After a fire destroyed Louis Wernwag's aesthetic wooden covered bridge in Philadelphia during the summer of 1838, Charles Ellet, chief engineer of the James River and Kanawha Canal in Virginia, proposed that the quickest and cheapest way to replace the bridge would be the construction of a French-type fil-de-fer cable suspension bridge, America's first. In April 1839 Ellet published A Popular Notice of Suspension Bridges in which he described French fil-de-fer bridges and detailed how such a structure could be built across the Schuylkill.[2]

Ellet's treatise stirred up considerable attention, D. K. Minor, an enthusiastic supporter of Ellet and publisher of the American Railroad Journal, contributing to the dissemination of Ellet's recommendations by publishing the treatise in its entirety in his journal. Thus, the ideas of Ellet came to the attention of Roebling, a recent subscriber to the journal. Impressed with Ellet's treatise, Roebling wrote to him on January 28, 1840:

> The study of suspension bridges, formed for the last few years of my residence in Europe, my favorite occupation; as this matter however appeared to be little cared for by Engineers in this country, I had no occasion whatever to bestow any further attention to it, while engaged in professional pursuits here.

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1. "Mr. John A. Roebling," Engineering, IV (October 18, 1867), 360-61, and Dictionary of American Biography, VIII, 86-89.

2. Charles Ellet, Jr., A Popular Notice of Wire Suspension Bridges (Richmond, 1839), pp. 1-12. Later when this treatise was published in Philadelphia in 1843 it included a description of Ellet's suspension bridge. Further information on the life and contributions of Ellet may be found in Gene D. Lewis, Charles Ellet, Jr.: The Engineer As Individualist,

Some publications of yours, which appeared in the R. R. Journal on the subject of Suspension bridges, revived in me the old favorite ideas, and I was very agreeably apprized by the report of your being now actually engaged in making preparations for constructing a wire cable bridge over the Schuylkill at Pha. and another over the Mississippi at St. Louis, which latter indeed would form the greatest construction of the kind in existence.

I have been informed that a like great undertaking is now in progress in Europe, the construction of a cable suspension bridge across the River Danube at Perth, which River resembles the Mississippi in nature & extent.

I cannot refrain from congratulating you upon the spirit with which you appear to enter upon this important undertaking, and which together with your familiar knowledge of the subject will no doubt insure you complete success.

Let but a single bridge of the kind be put up in Pha. exhibiting all the beautiful forms of the system to the best advantage, and it needs no prophesy to foretell the effect, which the novel and useful features will produce upon the intelligent minds of the Americans.

You will certainly occupy a very enviable position, in being the first Engineer, who, aided by nothing but the resources of his own mind and a close investigation, succeeds to introduce a new mode of construction, which here will find more useful application than in any other country. . . .

Perhaps I should be able to suggest to you an improvement in the construction of the saddles, applied by Mr. Telford on Minas bridge, in supporting the chains on top of the towers, calculated to facilitate the motion of the chains in the saddles in consequence of the contraction and expansion of the chains or cables. . . .

Should you at some future period be desirous of engaging an Ass. for the construction of Suspension bridges, who is competent for the task, and who at the same time would execute with pleasure all the necessary drawings, please bear me in mind.[3]

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2. (Cont.) 1810-1862 (Urbana, 1968), and Emory L. Kemp, "Ellet's Contribution to the Development of Suspension Bridges," Engineering Issues - Journal of Professional Activities, ASCE, XCIX (paper 9872, July 1973), 331.

3. Roebling to Ellet, January 28, 1840, Letters to John A. Roebling - Sundry Letters and Reports by John A. Roebling, Roebling Collection, Box 2, Rutgers, The State University.

Ellet responded to Roebling with an encouraging letter on February 8, 1840. He observed:

> It has given me much pleasure to learn that you have not neglected the subject of suspension bridges, in pursuing your professional studies abroad; and that you consequently appreciate the merits of that system of construction. It is my intention to endeavor to introduce this improvement in the United States; and shall accordingly pursue those means which appear to me most suitable to convey information to the publick, in the premises, and extend a knowledge of their powers and the principles of their equilibrium.
>
> I have already had one adopted at Philadelphia, and am now engaged in a report for another, and a much more important one, for the Mississippi at St. Louis.
>
> You correctly estimate the character of the American people, in supposing that they will not fail to recognize the merits of these structures when furnished with one respectable specimen.
>
> Should the system prevail, as I have reason to believe it will, I hope to have the pleasure of engaging the services of one who is familiar with the subject, and whose aid cannot but be valuable.[4]

Although the correspondence and blossoming friendship between the two engineers lasted little more than a year, their friendly letters during this period not only reawakened Roebling's interest in suspension bridge construction but also led to the establishment of the American wire rope industry.[5] In the spring of 1841 Roebling had completed the last of his railroad surveying jobs. During that survey he had traveled on the Allegheny Portage Railroad for the first time. The 40-mile inclined railway between Hollidaysburg and Johnstown was an important link

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4. Ellet to Roebling, February 8, 1840, quoted in Hamilton Schuyler, The Roeblings: A Century of Engineers, Bridge - Builders and Industrialists (Princeton, 1931), pp. 55-56.

5. For more information on the relationship of Ellet and Roebling see Donald Sayenga, "Ellet and Roebling," Proceedings of the Canal History and Technology Symposium, I (January 30, 1982), 114-54, and ibid., Ellet and Roebling (York, 1983).

between the eastern and western sections of the Pennsylvania Main Line. The canal boats were moved in specially-constructed wheeled cradles up and down the steep slopes by cables, generally about 3 inches in diameter and made of Kentucky hemp. Roebling conceived the idea (and was encouraged by Ellet) of substituting for these hempen cables, which were subject to severe usage and frequent replacement, ropes of twisted wire which would give greater strength and longer life along with the advantage of having a smaller diameter. After a number of experiments he patented and manufactured the first wire rope in America in a small factory at Saxonburg equipped with machinery of his own design and fabrication. In 1842 Roebling installed a stranded wire rope on Plane No. 3 of the Allegheny Portage Railroad at his own expense. The experiment proved to be successful and wire ropes were soon introduced on all the inclines. Roebling wrote an article in the American Railroad Journal in November 1843 detailing his achievement and obtained a patent on a portion of his stranding process. Ultimately, Roebling more than 200 wire ropes at Saxonburg and sold most of them to the Allegheny Portage Railroad, the Delaware and Hudson Canal Gravity Railroad, and the Morris Canal. In 1849 he moved his wire rope works to Trenton, New Jersey.[6]

While he was conducting his wire rope experiments at Saxonburg, Roebling determined to enhance his stature as a "bridge engineer" by

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6. John A. Roebling, "American Manufacture of Wire Ropes for Inclined Planes, Standing Rigging, Mines, Tillers, Etc.," American Railroad Journal, XVI (November, 1843), 321-34. A copy of this article may be seen in Appendix I. A broadside entitled "Patent Wire Rope of John A. Roebling" may be seen in Appendix J. For more information on the history of the wire rope industry see: Don Sayenga, "America's First Wire Rope Factory," Canal Currents, No. 55 (Summer 1981), I, 3-5; John Kimberly Mumford, Outspinning the Spider: The Story of Wire and Wire Rope (New York, 1921); F. R. Forestier - Walker, A History of the Wire Rope Industry of Great Britain (London, 1952); Roebling to Commissioner of Patents, March 27, 1841 (including Specification), and Roebling to Devine, May 31, 1844, Letters to John A. Roebling - Sundry Letters and Reports by John A. Roebling, Roebling Collection, Box 2, Rutgers, The State University; "On the Manufacture of Whim Ropes from Iron Wire," Journal of the Franklin Institute, XIX (May 1837), 369-73; and Schuyler, The Roeblings, pp. 48-56, 72-84.

submitting a two-part essay on wire cable suspension bridges to the American Railroad Journal. In the essays he displayed the results of his studies, made a number of recommendations, and posed as a wire bridge expert. He urged that more wire bridges be built by "the most eminent engineers," implying that he was one in that category.[7]

The articles made no mention of Ellet and this slight, together with Ellet's discovery that a rival, Andrew Young, who intended to use Roebling as his engineer, was manipulating to become prime contractor of the wire bridge at Philadelphia, ended the friendship between Ellet and Roebling.[8] Hearing of the competition for the wire bridge contract, Ellet

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7. John A. Roebling, "Some Remarks on Suspension Bridges, And On the Comparative Merits of Cable and Chain Bridges, No. 1," American Railroad Journal, XII (March 15, 1841), 161-66, and ibid., "No. 2," American Railroad Journal, XII (April 1, 1841), 193-96. A copy of this two-part treatise may be seen in Appendix K. It is interesting to note that an article concerning French observations on the advantages and disadvantages of employing iron or bar wire in suspension bridges appeared in the American Railroad Journal several months later. M. Le Blanc, "Observations Upon the Comparative Advantages and Inconveniences of the Employment of Iron Wire, or Bar Iron, in the Construction of Suspension Bridges of Great Span," American Railroad Journal, XIII (July 1, 1841), 3-7.

8. In May 1841 Charles L. Schlatter, principal engineer of the State of Pennsylvania, wrote a letter to Henry Spackman at the request of Andrew Young. In the letter Schlatter praised the knowledge of Roebling in planning and constructing suspension bridges:

> It affords me the greatest satisfaction to be enabled to give Mr. Roebling the highest testimonial in my power respecting his qualifications to plan and superintend such a structure. . . .
>
> Mr. R. has been associated with me in the State service more than two years, as my Principal Assistant, during which time he has given me the most entire satisfaction. His mechanical and scientific attainments have been of great service to me, and in the many conversations we have had during the time I have been acquainted with him relative to Suspension Bridges . . . he has shown that he is perfectly acquainted with their principles and construction.

Schlatter to Spackman, May 7, 1841, Letters to John A. Roebling - Sundry Letters and Reports by John A. Roebling, Roebling Collection, Box 2, Rutgers, The State University.

ousted the rival by purchasing a controlling share of the bridge stock, and after receiving the contract completed the bridge in six months. The structure was opened on January 1, 1842, amid great fanfare, and Ellet described the structure in A Popular Notice of Suspension Bridges, With A Brief Description of the Wire Bridge Across the Schuylkill, at Fairmont.[9]

While Ellet was away in Europe the 14-year-old wooden aqueduct over the Allegheny River that linked the Pennsylvania Main Line Canal to Pittsburgh began to collapse.[10] Because the state treasury was plagued by massive debts, there was no funding for repairs. Thus, the state turned the structure over to the city which in turn offered a prize for the best and cheapest way to rehabilitate and reactivate the crumbling aqueduct. Roebling entered the contest and his design for a cable suspension aqueduct, the first of its kind in the United States, was selected. The winning plan included the following concepts: rebuilding of piers; mounting of a sturdier trunk, strong enough to support itself when empty; elimination of the heavy arches by substituting iron wire cables, carrying the weight of only water, in a suspension system similar to that used previously to carry all the weight.[11]

In his proposal Roebling observed that "a strong argument in favor of the suspension plan" was its permanence and durability. The "principal parts of a suspension aqueduct will be formed of iron and stone, which will last for centuries." The wooden parts (trunk and

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9. Charles Ellet, Jr., A Popular Notice of Suspension Bridges, With a Brief Description of the Wire Bridge Across the Schuylkill, at Fairmont (Philadelphia, 1843). The bridge was also described in "Suspension Bridges," American Railroad Journal, XVIII (December 18, 1845), 812.

10. A detailed description of the wooden aqueduct may be found in John C. Trautwine, "Description of the Wooden Aqueduct Carrying the Pennsylvania Canal Across the River Allegheny, at Pittsburg; from Actual Measurement," Journal of the Franklin Institute, IV, 3rd Series (July, 1842), 1-10.

11. Donald Sayenga, "The Original Pittsburgh Aqueduct," Canal Currents, No. 59 (Summer, 1982), 3.

beams) could be substituted with iron ones at any time "so as to render the whole structure imperishable, and insure the services of the aqueduct for the future. The difference of weight by the substitution of iron for the beams and trunk in place of wood, would be in favor of iron."[12]

Emulating Ellet, Roebling became the general contractor for the work, replacing the wooden aqueduct in 1844-45 with the lighter, stronger wire cable suspension structure built on the old piers, each of the two cables being 7 inches in diameter and consisting of seven strands of wire with some 1,900 parallel wires. The structure, which was opened to commerce in May 1845, consisted of seven spans, each 162 feet long with the canal trunk 14 feet in width at the bottom and 16-1/2 feet at the water line. The cables were the first to have the continuous spiral wrapping that had been advocated by the French engineer Vicat some decades earlier.[13]

Some years later the significance of the Allegheny Aqueduct was described in a biographical sketch of Roebling in Engineering--a sketch that Roebling probably wrote himself:

> A rigorous winter and an unusually rapid river added greatly to the difficulties to be overcome, heightened as they were by the entire novelty of the method of construction, and by the unavoidable imperfections of hitherto untried cable machinery, intended for the first time to make a large cable in the place . . . it was to occupy permanently.
>
> One satisfactory phase, however, in the history of that work, and indeed of a subsequent one also, was the practical refutation its success afforded to the numerous attacks of the engineering profession of that day, who scoffed at the bare

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12. "Suspension Aqueduct," American Railroad Journal, XVII (September, 1844), 276.

13. Sayenga, "Original Pittsburgh Aqueduct," 1-4; Don A. Sayenga, "Roebling's Pittsburgh Aqueduct," Canal Currents, No. 61 (Winter, 1983), 3-6; and H. J. Hopkins, A Span of Bridges: An Illustrated History (New York, 1970), p. 215.

idea of a suspension aqueduct, and predicted its downfall as soon as the water was let into it.[14]

As the Allegheny Aqueduct was nearing completion in 1845 a great fire swept through portions of Pittsburgh, destroying the wooden Smithfield Street Bridge over the Monongahela River. Soon a contract was let to Roebling to replace the destroyed bridge with a suspension bridge built on the old piers. The structure, which was completed in 1846, had eight spans of 188 feet in length each. The outside width of the bridge was 32 feet. The bridge was stiffened by diagonal stays 1.25 inches in diameter, and its two cables, each 4-1/2 inches in diameter, contained 750 wires. Unable to adopt the air-spinning method on this bridge, Roebling constructed the two cables on two separate land-based platforms, and then hoisted them into place from flatboats. The pendulum principle was applied to counterbalance adjoining spans under the action of unequal loads. Cast-iron towers were anchored to the old piers which were so narrow that Roebling had to ensure a near-vertical reaction at each tower, accomplished by providing inverted Y-shaped pendulums, to the legs of which he fastened cables which were discontinuous at the pendulums. The spinning process was accelerated by using larger wire than that on the Allegheny Aqueduct (1/6 inch instead of 1/8 inch).[15]

The significance of these two works was analyzed briefly by J. C. Adams, a design engineer from Pittsburgh, in the Engineering News--

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14. "Mr. John A. Roebling," Engineering, 360.

15. A. A. Jakkula, A History of Suspension Bridges in Bibliographical Form (Washington, 1941), p. 129; "Mr. John A. Roebling," Journal of the Franklin Institute, LIV (December, 1867), 411; Hopkins, Span of Bridges, pp. 215-16; G. Lindenthal, "The Monongahela Bridge," Engineering News and American Contract Journal, XI (May 24, 1884), 251-53, and (May 31, 1884), 265-66; S. M. Wickersham, "The Monongahela Suspension Bridge, at Pittsburgh, Pa.," Engineering News and American Contract Journal, X (May 26, 1883), 243-44; and S. M. Wickersham, "The Monongahela Suspension Bridge at Pittsburgh, Pa.," Scientific American Supplement, No. 389 (June 16, 1883), 6201-02.

Record in 1931. He noted that the construction of these bridges "contributed to the art and knowledge of suspension-bridge building":

> The cost of the aqueduct was $62,000, including the removal of the old wooden structure and revisions to the piers. For the Smithfield St. bridge the cost was $55,000, including revisions to the piers. Both bridges replaced wooden structures, that of the latter having been destroyed in the great fire of 1845.
>
> The suspenders for the Smithfield St. span were of charcoal iron 1.5 in. in diameter and spaced 4 ft. centers. Diagonal stays of 1.25 in. in diameter were used.
>
> Over the piers the cables for the aqueduct were constructed with swells made by introducing short wires at two points. These swells were wedged into corresponding recesses in the supporting saddles, thus fixing the cables to the piers. For the Smithfield St. spans the cables were attached to the towers by pendulums 2.5 ft. long. When a heavy load passed over any span, the maximum movement of the adjacent pendulum was observed to be not over 0.5 in.
>
> On both of these bridges, in the words of their builder: "Oxidation is guarded against by a varnish applied to each wire separately. Their preservation, however, is insured by close compact and continuous wrapping made of annealed wire and laid on by machinery in the most perfect manner. A continuous wrapping is an important improvement, which in this case has for the first time been successfully applied."
>
> It is of interest to consider the changes and advances in practice after a lapse of 85 years as regards unit stresses, loads, size of wires and cables, suspenders and suspender spacing, diagonal stays, stiffening girders and cable protection. The continuous wrapping of wire cables by machinery commonly used today, was a contribution from the first of these bridges.[16]

More recently, Donald Sayenga, an executive with the Bethlehem Steel Corporation who has devoted considerable study to the engineering contributions of Roebling and Ellet, has noted that the Smithfield Street Bridge effort was "a unique amalgam of techniques and experiments involving flexible spans, hollow towers, and cables equipped with a

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16. J. C. Adams, "Multiple-Span Suspension Bridges," Engineering News--Record, CVII (August 13, 1931), 270.

system of balancing pendulums." The two suspension bridge contracts in Pittsburgh provided Roebling with considerable "practical knowledge about such bridges, particularly methods for making and anchoring cables." Because of this work and his related studies and tests, Sayenga states that Roebling became "convinced the French engineering school had not adequately recognized the threat to suspension bridges posed by windstorms."[17] While he did not "really understand specifically how air caused problems," he "overdesigned to compensate for the dangers" and "became a leading exponent of stiffened floors, braced with guys and stays." On the other hand, Ellet "continued to subscribe to the French notion that a bridge floor must remain flexible to relieve itself of the imbalance created by loaded vehicles." While the study of aerodynamics was then only remote conjecture and theory, Sayenga observes that "Roebling must be applauded for his apprehension and conservation."[18]

In September 1846 Roebling prepared a report and plan for a wire suspension bridge over the Ohio River between Cincinnati, Ohio, and Covington, Kentucky. Although Roebling's plans were not accepted at the time because of lack of finances, the detailed report indicates that Roebling had become an authority on the practical implementation of the principles of suspension bridge engineering. The report contained lengthy descriptions for the anchorage, cables, suspenders, stays, flooring, foundations, piers, and ice breakers of the proposed bridge. In his introductory remarks, Roebling concluded that the "solution of the problem of crossing large and deep rivers with great spans and at high elevations, was left to modern

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17. One reason for Roebling's concern was the damage caused to the suspension bridge over the Menai Strait in England by a windstorm in January 1839. Observations relative to the damage may be found in W. A. Provis, "Observations on the Effect of Wind on the Suspension Bridge over the Menai Strait, More Especially with Reference to the Inquiries which its Roadways Sustained during the Storm of January 1839," Journal of the Franklin Institute, III, 3rd Series (March 1842), 210-14. Also see "Suspension Bridges," Scientific American, VIII (November 20, 1852), 78.

18. Sayenga, Ellet and Roebling, pp. 28-29, and Sayenga, "Ellet and Roebling," 130-31.

engineering. It has been fully solved by the application of the principle of suspension."[19]

By 1847 Roebling had established a well-deserved reputation as a designer/ builder of suspension bridges, and Ellet had become involved in plans to convert the Ohio-Mississippi drainage network into an enormous canal system with the canals formed in the rivers themselves, regulated by impoundment and release of natural water and controlled by tributary dams.[20] In that year, however, several of Ellet's half-forgotten bridge proposals were revived after the American economy recovered from the abysmal years of the late 1830s and early 1840s. As a result Ellet ultimately received contracts for the construction of suspension bridges at the Niagara Gorge and the National Road across the Ohio River at Wheeling despite the fact that Roebling submitted plans for each.[21]

Although Roebling was unsuccessful in obtaining the contracts for the Cincinnati, Niagara Gorge, and Wheeling bridges in 1846-47, he obtained two patents on suspension bridge construction during this period. The patents were based on techniques of suspension bridge construction that he had developed as part of his efforts on the

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19. John A. Robeling, Report and Plan for a Wire Suspension Bridge, Proposed To Be Erected Over the Ohio River at Cincinnati (Cincinnati, 1846), pp. 1-33.

20. Despite his interest in bridge and aqueduct construction, Roebling found time in 1847 to prepare a paper for the Pittsburgh Board of Trade in which he advocated a railroad from Philadelphia to St. Louis. Later in 1850 Roebling wrote to the Journal of Commerce, expressing his conviction that a transatlantic telegraph was feasible. John A. Roebling, "The Great Central Railroad from Philadelphia to St. Louis," American Railroad Journal, XX (1847), 122-25, 134-35, 137-41, 155-57, and Schuyler, The Roeblings, pp. 65-71, 87-88.

21. Sayenga, "Ellet and Roebling," pp. 132-33, and Sayenga, Ellet and Roebling, pp. 31-33. After a tornado damaged the Wheeling bridge in 1854, Roebling was called to make the repairs. He united the separate strands on each side into solid cables and placed them farther apart at the towers than at the center, thus making the bridge more rigid against wind pressure. Schuyler, The Roeblings, pp. 117-18.

Allegheny Aqueduct and Smithfield Street Bridge in Pittsburgh. The two patents were for "Anchoring Suspension--Chains for Bridges," (Patent No. 4710, dated August 26, 1846) and "Apparatus for Passing Suspension--Wires for Bridges Across Rivers, Etc.," (Patent No. 4945, dated January 26, 1847).[22]

The technique Roebling used in the anchorages of the Allegheny Aqueduct was a variation of the French methods. Normally, an underground air chamber was built to allow drying and inspection of the chains and cables. His theory, which he patented, was that a chemical reaction between moisture and his cement/mortar mixture would form a "calcareous coating" on the iron links, eliminating the need for inspection.

The idea of passing suspension wires across rivers with a traveling rope had been designed by the French engineer Vicat. Roebling, however, was the first to use a spinning wheel as part of the process on the Allegheny Aqueduct. On June 6, 1846, he applied for a patent on his method of passing suspension wire, at which time he was not aware of Vicat's earlier work. He then refiled his petition on September 19, 1846, to obtain protection on his apparatus only.[23]

Following the years 1847-50, during which he constructed the four Delaware and Hudson Canal wire cable suspension aqueducts, Roebling attracted admiration and achieved a measure of high standing among the engineers of his day. Thus, Roebling realized his ambition--that of a

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22. Patents Nos. 4710 and 4945, Records of the Patent Office, Record Group 241, National Archives. Copies of the two patents may be seen in Appendixes L and M. Also see U. S. Congress, House, Annual Report of the Commissioner of Patents: Report of the Commissioner of Patents, for the Year 1846, 29th Cong., 2d sess, 1847, H. Doc. 52, pp. 298-99; U. S. Congress, House, Annual Report of the Commissioner of Patents, for the Year 1847, 30th Cong., 1st sess., 1848, H. Ex. Doc. 54, p. 74; Mary Raimonde Bartus, "John August Roebling: Inventor and Bridgebuilder" (unpublished M. A. thesis, Fordham University, 1957), p. 84; and Schuyler, The Roeblings, pp. 89-92.

23. Sayenga, "Roebling's Pittsburgh Aqueduct," 4, 6.

prominent builder of suspension bridges. Since 1844 he had built six such structures, five of them carrying canal aqueducts. In his projects he had found the opportunity to try out the ideas that had been crowding his mind during the preceding years. No other bridgebuilder of the time could boast of having built six suspension structures. Yet while the erstwhile immigrant had become a foremost exponent of the art of suspension bridge construction, he was still seeking new worlds to conquer. The thought that the cable suspension system might be used for railroad bridges had become a fixed idea in his mind. This conception was the seed of Roebling's next great achievement.[24]

B. CAREER AND ACCOMPLISHMENTS OF ROEBLING AFTER CONSTRUCTION OF DELAWARE AND HUDSON CANAL AQUEDUCTS

The list of Roebling's works in the field of suspension bridge construction during the 1850s and 1860s put him at the forefront of his profession. Perhaps, the most striking structure was the pioneer railroad wire cable suspension bridge which he built at Niagara Falls in the years 1851-55. Despite the natural obstacles to be overcome and the outbreak of a cholera epidemic at the site, Roebling succeeded in building a structure that brought him enormous prestige and international fame. Having a clear span of 825 feet, the bridge was supported by four wire cables of 10 inch diameter each. The bridge had two floors--the lower one for vehicles and the upper one for railway tracks. The two floors were connected by struts and diagonal tension rods so that the superstructure formed a continuous hollow girder stiff enough to support the action of a rolling load, the weight being supported by the cables.[25]

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24. David B. Steinman, The Builders of the Bridge: The Story of John Roebling and His Son (New York, 1950), p. 106.

25. "Mr. John A. Roebling," Engineering, 361; Schuyler, The Roeblings, pp. 93-97, 122-24; Tyrrell, History of Bridge Engineering, pp. 225-27; Charles B. Stuart, Lives and Works of Civil and Military Engineers of America (New York, 1871), pp. 306-09; and Final Report of John A. Roebling, Civil Engineer, to the Presidents and Directors of the Niagara Falls Suspension and Niagara Falls International Bridge Companies, May 1,

The significance of the Niagara Railroad Bridge has been examined by Sir Alfred Pugsley in his The Theory of Suspension Bridges. According to Pugsley, a new approach to stiffening suspension bridges was arising:

> . . . Whereas Robert Stephenson, when designing the Britannia Tubular Bridge (1845), had argued that stiffening by means of deck girders would necessitate such large girders that the cables and suspension system might be dispensed with, Peter Barlow . . . showed by a series of model experiments that much weaker girders would, in fact, be sufficient to spread local loads on to the cables and so avoid large deflections. It was as a result of this that Rankine produced his approximate theory for two and three hinged stiffening girders that has been used so much ever since. By assuming that any concentrated load was spread by the girder uniformly across the whole span on to the cables, he produced the first rational theory of the interaction of cable and girder. At the time, of course, the bridges concerned were of spans of only a few hundred feet, and the stiffening girder was being advocated as an alternative to the inclined rods of Motley and others. It was thus natural for John A. Roebling, in America, when he built his first long span railway bridge, that of 821 ft. span over the Niagara Falls, to combine all three methods--the normal cables with vertical rods, the inclined rods radiating from the towers, and the deep heavy stiffening girder; and he did so with such success that the first locomotive (weighing 23 tons) to pass over the bridge caused a central deflection of only 3 1/2 in. . . .
>
> It was at this stage that the importance and influence of the bridge weight itself upon the bridge stiffness was first realised. . . .
>
> Roebling, from his Niagara experience, had evidently gained an intuitive understanding of the stiffness of a heavy suspension bridge of long span due to gravity forces. This, and his practical development of the construction of wire cables for suspension bridges, led Roebling finally to the successful design and--in 1883, after his death--the successful completion of the great Brooklyn Bridge of 1596 ft span. The stiffening girders of the Niagara Bridge, between its upper and lower decks, were 16 ft deep--i.e. about one-fiftieth of its span; the main trusses of the Brooklyn Bridge are only 17 ft deep--i.e. about one-ninetieth of its span. Roebling still clung to the

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25. (Cont.) 1855 (Rochester, 1855), pp. 1-47. The "table of quantities" for the Niagara Railroad Bridge may be seen on the following page.

TABLE OF QUANTITIES.

Length of Bridge from centre to centre of tower, ...	821	ft. 4 in.
" Floor between towers, ...	[illegible]	"
Number of Wire Cables, ...	4	"
Diameter of each "	10	inches
Solid Wire Section of each Cable, ...	60.40	sq. in.
Aggregate " " of the four Cables, ...	241.60	"
Aggregate Section of Anchor chains, lowest links, ...	276.00	"
" " " upper links, ...	372.00	"
Ultimate strength of Chains, ...	11904	tons.
Aggregate number of Wires in Cables, ...	14560	
Average strength of one Wire, ...	[illegible]	lbs.
Ultimate strength of four cables, ...	12000	tons.
Permanent weight supported by Cables, ...	1000	"
Tension resulting, ...	1810	"
Length of Anchor Chains, ...	66	ft.
" " upper Cables, ...	1261	"
" " lower "	1193	"
Deflections of upper Cables at medium temperature, ...	54	"
" lower " " "	64	"
Average deflection, ...	59	"
Number of Suspenders, ...	624	
Aggregate ultimate strength of Suspenders, ...	18720	tons.
Number of Overfloor Stays, ...	64	
Aggregate strength "	1920	tons.
Number of River Stays, ...	56	
Aggregate strength "	[illegible]	tons.
Elevation of Railway track above middle stage of river,	245	ft.

Final Report of John A. Roebling . . . May 1, 1855, p. 46.

> radiating inclined suspension rods of his earlier designs, but was clearly becoming more confident of the cable gravity stiffness associated with long spans. . . .[26]

Following the completion of the Niagara Railroad Bridge, Roebling completed two other notable suspension bridges with the help of his son Washington who graduated from Rensselaer Polytechnic Institute in 1857.[27] In 1856 John began building towers for a 1,400-foot suspension bridge over the Ohio River between Covington, Kentucky, and Cincinnati, Ohio, using revised plans from those he had submitted earlier in 1846. The Panic of 1857 intervened, however, and later the outbreak of the Civil War prevented the completion of this bridge until 1867. The bridge's span of 1,057 feet was the widest wire cable suspension span in the world constructed to that date and was heralded by Engineering as "undeniably the finest of its kind ever constructed" and "undoubtedly the finest work structurally and architecturally, of its class."[28]

During construction of the Niagara Railroad Bridge Roebling commenced another railway suspension bridge over the 1,224-foot gorge of the Kentucky River on the projected line of the Lexington and Southern

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26. Sir Alfred Pugsley, The Theory of Suspension Bridges (London, 1957), pp. 4-6.

27. Washington A. Roebling wrote a paper entitled "Design for a Suspension Aqueduct" for his graduation thesis in 1857. The study contained construction guidelines, calculations, and drawings for an Erie Canal aqueduct "at the falls of the Poestmkill, a creek running from East to West through Rensselaer County, and emptying into the Hudson in South Troy." Washington A. Roebling. Thesis. Rensselaer Polytechnic Institute Class of 1857. "Design for a Suspension Aqueduct." Roebling Collection, Rensselaer Polytechnic Institute.

28. Schuyler, The Roeblings, pp. 125-28; Tyrrell, History of Bridge Engineering, pp. 231-33; "The Cincinnati Bridge," Engineering, IV (October 11, 1867), 335; Reports on the Ohio Bridge, at Cincinnati: Report of John A. Roebling, Civil Engineer, to the President and Board of Directors of the Covington and Cincinnati Bridge Company, April 1, 1867 (Cincinnati, 1867); and "The Cincinnati Suspension Bridge," Engineering, IV (July 12, 1867), 22-23; (July 19, 1867), 49; (July 26, 1849), 74-76; (August 9, 1967), 98-99; (August 16, 1867), 140-41. The table of quantities for this bridge may be seen on the following page.

Main span from centre to centre of towers ...	1057 ft.
Side spans from abutment to centre of tower ...	281 ,,
Total length between abutments	1619 ,,
Elevation of floor above low water at tower ...	91 ,,
,, ,, ,, in centre ...	103 ,,
,, of Front-street, Cincinnati approach ...	60 ,,
,, of Second ,, Covington ,, ...	71 ,,
Ascent of Cincinnati approach in 100 ft.	5 ,,
Length of Cincinnati approach from Front-street to abutment	311 ,,
Length of Covington approach from Second-street to abutment	292 ,,
Total length, including approaches	2252 ,,
Number of cables	2
Diameter of each	$12\frac{1}{3}$ in.
No. 9 wires in each cable	5200
,, ,, both cables	10,400
Average strength of one wire	1620 lb.
Ultimate strength of one cable	4212 tns.
,, ,, of both cables	8424 ,,
Number of stays in main span	76
Strength of each	90 tns.
Aggregate strength of stays	6840 ,,
United strength of cables and stays	15,264 ,,
Weight of main span between towers	1500 ,,
,, ,, as far as supported by cables	1300 ,,
Deflection of cables in main span	89 ft.
Permanent tension to strength	1÷8
Ordinary working tension to strength	1÷7
Maximum tension to strength	1÷6
Section of each anchor chain in square inches ...	190
,, two ,, ,, ,, ...	380
Ultimate strength of two chains	9500 tns.
Elevation of anchor-plates above low water ...	25 ft.
Greatest weight resting upon the foundation of each tower	32,000 tns.
Area of each foundation	8250 s.ft.
Pressure upon each superficial foot	3.88 tns.
Cubic content of masonry of each tower	400,000 ft.

"The Cincinnati Suspension Bridge," Engineering, IV (August 16, 1867), 141.

Kentucky Railroad extending from Cincinnati to Chattanooga. The anchorages were laid and the stone towers erected for the bridge when financial problems of the railway company caused the work to be suspended indefinitely. The bridge had been designed on the "girder principle" without a carriageway as constructed on the Niagara Railroad Bridge.[29]

During the delay of the Ohio River Bridge Roebling received the contract to replace a wooden bridge built over the Allegheny River at Pittsburgh in 1818 with an iron highway suspension structure that featured elaborate ornamentation. The work, which consisted of the removal of the old structure and construction of three new masonry piers, took three years from 1858 to 1860. According to Charles B. Stuart the total length of the bridge was

> one thousand and thirty feet, divided into two spans of three hundred and forty-four feet each, and two side spans of one hundred and seventy-one feet each. The floor has a width of forty feet, including two sidewalks, ten feet wide. The frame work of the superstructure is composed essentially of iron girders, with a flooring of wood. Ornamental open towers of cast-iron support the cables, which are four in number, two of seven inches in diameter, attached to the floor between the sidewalks and carriage-way, and two of four inches in diameter, attached to the ends of the floor beams; in addition to the cables, there is an effective system of stays.[30]

The completion of the Ohio River Bridge at Cincinnati in 1867 renewed discussion about the construction of a suspension bridge over the Mississippi at St. Louis. This proposed work appealed to Roebling and he began preparation of a manuscript that was published posthumously by his son Washington after his death in 1869. In _Long and Short Span Railway Bridges_ Roebling included detailed sections on

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29. Stuart, _Lives and Works of Engineers_, p. 311; "Mr. John A. Roebling," _Engineering_, 361; Schuyler, _The Roeblings_, pp. 124-25; and Tyrrell, _History of Bridge Engineering_, p. 228.

30. Stuart, _Lives and Works of Engineers_, pp. 316-17; Schuyler, _The Roeblings_, p. 129; and Tyrrell, _History of Bridge Engineering_, p. 228.

the following: (a) theory of the parabolic truss; (b) general description of a single-track iron railway bridge; (c) plan of a bridge over the Mississippi River, at St. Louis, for railway and common travel; (d) railroad bridge over the Ohio; and (e) short-span bridges.[31]

Roebling's disappointment at losing the competition for the St. Louis bridge contract to James B. Eads, who proposed to erect a cantilevered tubular steel arch, was assuaged by his appointment in May 1867 as chief engineer for a suspension bridge across the East River connecting Lower Manhattan and Brooklyn--a project he had recommended ten years earlier. Roebling and his son Washington prepared plans and estimates and Engineering observed on July 12, 1867:

> As a whole, no work of the same character, yet executed, approaches this in magnitude. It will undoubtedly be the crowning work of Mr. Roebling's life, and we may, not unreasonably conclude that it will hand his name down to posterity as one of the greatest engineers of modern times. . . .[32]

Roebling himself had a full appreciation of the magnitude of the East River undertaking. In 1867 he wrote to the president and directors overseeing the project:

> The contemplated work, when constructed in accordance with my designs, will not only be the greatest bridge in existence, but it will be the great engineering work of this Continent and of the age. Its most conspicuous features--the great towers--will serve as landmarks to the adjoining cities, and they will be entitled to be ranked as national monuments. As a great work of art, and as a successful specimen of advanced bridge engineering, this structure will forever testify to the energy, enterprise, and wealth of that community which shall secure its erection.[33]

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31. John A. Roebling, Long and Short Span Railway Bridges (New York, 1869).

32. "Suspension Bridges," Engineering, IV (July 12, 1867), 25.

33. Quoted in Stuart, Lives and Works of Engineers, p. 322.

While Roebling was proceeding to finalize the plans for the Brooklyn Bridge his contributions to suspension bridge engineering technology were assessed by Charles Bender in his paper "Historical Sketch of the Successive Improvements in Suspension Bridges to the Present Time," read before the American Society of Civil Engineers on March 18, 1868. Bender observed:

> The French methods and designs [particularly those of Navier and Vicat] have been used in our country; especially the method of constructing the cables directly on the towers, in the year 1844, at the Alleghany suspension bridge, near Pittsburg, and Vicat's invention was a little, but not essentially, modified at the construction of the Niagara and Cincinnati suspension bridges by Roebling. . . .
>
> During this time [the 1850s] the American engineers, occupied in improving the wooden truss-bridges, did not forget to appreciate suspension bridges, and that they constructed the greatest spans is well known. I mention the former Niagara bridge, of one thousand and forty-two feet span. . . .
>
> At the time when the Britannia tubular bridge was to be built, R. Stephenson proposed a stiff suspension bridge, in the form of an iron tube, suspended by chains. Many and costly models were built, as at this time no theories existed either of truss or of suspension bridges. The tubes in these models were made stronger and stronger after every experiment; and, lastly, the chains were no longer necessary and were dispensed with, and the iron tubular bridge was the result.
>
> It is plain that the Niagara railroad bridge is the direct application of Stephenson's plan.
>
> This work, as well as the Cincinnati bridge, are sufficiently known, and therefore I do not consider it to be necessary to describe them, nor to demonstrate that they are to be appreciated as great works of American enterprise and boldness, but exhibit nothing commendable in the way of invention.[34]

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34. Charles Bender, "Historical Sketch of the Successive Improvements in Suspension Bridges to the Present Time," Transactions, American Society of Civil Engineers, I (1868), 40, 42-43. Roebling did not agree with Bender's assessment of his use of French methods and designs. The year before Roebling had discussed the differences between the French system of "cable making" and his own system in Reports on the Ohio Bridge, at Cincinnati . . . April 1st, 1867, pp. 48-52. A copy of his remarks on this subject may be seen in Appendix O.

The plans for the Brooklyn Bridge received approval early in 1869 and surveys were quickly commenced. On June 28, 1869, while Roebling was watching his son perform some preliminary surveys, a boat entering the Fulton Ferry slip on the Brooklyn side pushed back the piling on which he was standing, catching his foot and crushing several of his toes. Although the toes were amputated, tetanus set in and he died of lockjaw on July 22 at the age of 62.[35]

In 1871 Charles B. Stuart, the noted biographer of civil and military engineers, paid an eloquent tribute to his long-time friend Roebling. He observed:

> The name of John A. Roebling will always take high rank among the Engineers of America. He was one of many of our foreign-born citizens who have, by their genius and learning, adorned and reflected honor on the country of their adoption. He was a man of whom the engineering profession may justly be proud. His name, with eminent fitness, may take a conspicuous place with the most honorable and zealous in the work of internal improvement and human progress.
>
> The life of Roebling was one of study and labor--a life too soon terminated. He died just after entering upon the development of one of the grandest conceptions of his professional career. But were men's lives measured by what they accomplish, by the good they have done, he lived more than most men who see a greater number of years.

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34. (Cont.) The historical development of suspension bridge construction as well as Roebling's place in the evolution of that development is treated further in Tyrrell, History of Bridge Engineering, pp. 202-56; E. L. Kemp, "Links in a Chain: The Development of Suspension Bridges 1801-70," The Structural Engineer, LVIIA (August, 1979), 255-63; Pugsley, The Theory of Suspension Bridges, pp. 1-10; Hopkins, A Span of Bridges, pp. 174-236; and Mahan, An Elementary Course of Civil Engineering, pp. 251-64, 269-76; Charles Stewart Drewry, A Memoir on Suspension Bridges, Comprising the History of Their Origin and Progress, And of Their Application to Civil and Military Purposes (London, 1832); James Hann et al., The Theory, Practice, and Architecture of Bridges of Stone, Iron, Timber, and Wire; With Examples on the Principle of Suspension, 2 vols. (London, 1839); and M. Navier, Rapport A Monsieur Becquey, Conseiller D'Etat, Directeur General Des Ponts Et Chaussees Et Des Et Memoire Sur Les Ponts Suspendus . . . (Paris, 1823).

35. Stuart, Lives and Works of Engineers, p. 326.

. . . He always declined to furnish plans for an important structure . . . that could not be erected under his personal supervision, neither would he undertake work upon plans made by others. He was not an imitator; all his great constructions were esentially different, and planned to meet the special features of the location, and when he had once decided upon his plan, he was sanguine of its success, and his whole energies were directed to its accomplishment.[36]

Roebling's son Washington took charge of the construction operations of the Brooklyn Bridge, and on May 24, 1883, President Chester A. Arthur led the parade over the Brooklyn Bridge at the grand opening ceremonies. In its initial days the bridge was hailed as a triumph of intuitive engineering and was commonly referred to as "The Eighth Wonder of the World." For nearly fifty years after its completion it reigned supreme as the most magnificent suspension bridge on earth. It raised such enthusiasm in America that the suspension bridge came to the fore for all new long-span world experts in suspension bridge engineering.[37] Some years later the American Society of Civil Engineers, an organization of which John A. Roebling was elected to membership on December 2, 1868, noted in its memoir of the noted engineer:

The crowning achievement of his life was the conception of the Brooklyn Bridge, spanning the East River, between Manhattan and Brooklyn. This is indeed a marvel of daring skill, the work of a master mind--and a monument to its designer. . . .[38]

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36. Ibid., pp. 301, 309-10.

37. A number of works have been published on the history of the Brooklyn Bridge. Among these are David McCullough, The Great Bridge (New York, 1972); David McCullough, "The Great Bridge and the American Imagination," The New York Times Magazine, March 27, 1983, 29-34, 36, 38, 68-69, 80; Alan Trachtenberg, Brooklyn Bridge: Fact and Symbol (Chicago, 1965); and Tyrrell, History of Bridge Engineering, pp. 237-38.

38. "John Augustus Roebling, M. Am. Soc. C. E., Died July 22, 1869," Transactions, American Society of Civil Engineers, XCVIII (1933), 1614-18.

This view was further amplified by David B. Steinman and Sara Ruth Watson, historians of bridge construction, in their Bridges and Their Builders:

> Because it was the crowning achievement of John Roebling's career, because it was a miracle for its age, because it strikingly symbolized man's conquest over the forces of nature, because it took another Roebling's health and career, because it is an outstanding symbol of the American tradition of achievement--for all these reasons there is only one Brooklyn Bridge, a structure standing out by itself in the panorama or bridgebuilding of all ages. . . .
>
> John A. Roebling was one of those rare geniuses who come generations before their time. The Brooklyn Bridge, in form and pattern, in composition and proportion, is his creation. It was built as he had conceived it. It is an artistic as well as an engineering masterpiece.
>
> The pierced granite towers, the graceful arc of the main cables, the gossamer network of lighter cables, and the arched line of the roadway combine to produce a matchless composition, expressing the harmonious union of power and grace. It is a thing of enduring beauty.[39]

While not the first engineer to construct wire cable suspension bridges, Roebling was an "early person in the art" and contributed to the art by perfecting the process and adding "elements of strength, rigidity and longevity as his special contribution." He was the first to construct wire cable suspension bridges to carry trains. Long-span "bridges of a thousand feet and over" were also first successfully constructed by him. Hence Roebling made a significant contribution to wire cable suspension bridge technology.[40]

The death of Roebling, as well as that of Ellet in 1862, marked the end of the early period of the modern suspension bridge according to Emory L. Kemp, a professor in the history of engineering and technology

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39. David B. Steinman and Sara Ruth Watson, Bridges and Their Builders (New York, 1941), pp. 234, 248.

40. Schuyler, The Roeblings, p. 117.

at West Virginia University. In an article, entitled "Links in a Chain: The Development of Suspension Bridges, 1801-70," he observed:

> The early history of the modern suspension bridge is an important subject in its own right. It, however, also provides a good example of the transformation of a primitive technology into an important and most impressive modern method for building long-span bridges. This development was made possible by the use of wrought iron, which was then effectively a new structural material, in a most efficient manner--direct tension.
>
> A galaxy of outstanding engineers in France, Britain and America was responsible, for a 50-year period, for the modern suspension bridge with spans in excess of 300 m clear span. This development represents a "conjunction of stars" such as Telford, Brown, Navier, Sequin, Vicat, Finley, Ellet and Roebling.
>
> Each made a significant contribution to this technology, not in isolation, but in relation to a growing tradition that included the application of theory to design, the use of experimental testing techniques and the invention of special construction methods. By using a flexible tendon as the principal component, engineers were forced to wrestle with the concept of stiffness and dynamic stability for the first time. These pioneer suspension bridge builders were to find, through bitter experience, that there is more to a successful bridge design than the provision of adequate strength only. . . .

After the deaths of Ellet and Roebling a new era in suspension bridge construction was ushered in with "the use of steel wires and stiffening trusses, more sophisticated analytical methods and much improved construction techniques."[41]

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41. Kemp, "Links in a Chain," 255, 262.

CHAPTER SIX

OPERATION AND MAINTENANCE OF THE DELAWARE AQUEDUCT: 1849-99

The Delaware Aqueduct served as a key structure of the Delaware and Hudson Canal for five decades from 1849 to 1899. Apparently, there were no major problems related to its operation and only routine and periodic maintenance work were carried out on the aqueduct.

Few reminiscences of the Delaware Aqueduct by canallers have been recorded. An exception was a speech by Du Bois Weber, a former boatman, given at the Ellenville Public Library in October 1952:

> . . . Whoever came in the aqueduct had the right of way. He had to look first to see whether another boat was coming, because the aqueduct was only large enough for one boat to go through at a time. One time I saw a raft go down that river right through under the aqueduct. I often wondered how they stopped the rafts in the current of the river, so I asked a man one time. They'd steer for the eddies and get close enough to them so they'd be hurled around then and get close enough to the shore to throw a line out and fasten it to a tow line. They always had to figure on some eddy to tie the rafts up and they had to know whether they were going to get there before dark. The river had to be a certain height before they started the rafts out. . . .
>
> . . . before the canal closed, a stable had been built there [near New York end of the Delaware Aqueduct]. For the stable they charged you 10¢ a night to put the horses in the stable overnight. If they gave you hay, they charged you 15¢ more. They didn't change teams, but worked the same team all day long.[1]

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1. "The D and H Canal," Speech by Du Bois Weber, Ellenville Public Library, October 9, 1952, in "The D & H Canal: Stories, Etc.," Ellenville Public Library and Museum. The perils of rafting under the Delaware Aqueduct are also described in Leslie C. Wood, Rafting on the Delaware River (Livingston Manor, New York, 1934), pp. 17-19, 88-91. A photograph of the Delaware Aqueduct dated 1890 shows several wooden structures on the north side of the New York abutment which are said to be stables and sheds.

The Delaware and Lackawaxen aqueducts were also mentioned in an old canal song entitled "A Trip Down the Canal" by "Spot" McLaughlin. One stanza of this ditty went:

> Now we are at Ridgeway's three locks--
> You can leave your bow line slack
> When we go through the Aqueduct
> To cross the Lackawack.
> We went another half mile. Tom Tierney
> For some light boats had to wait
> Here we crossed the Delaware
> And went over into New York State.[2]

During its fifty-year utilization as a canal structure illustrations of the Delaware Aqueduct appeared in several significant publications. In 1874 a contemporary view (a copy of which may be seen on the following page) of the structure appeared in William Cullen Bryant's Picturesque America. Later in 1887 a view of the aqueduct appeared in P. L. Tucker's The Erie Route.[3]

In March 1853 the Delaware and Hudson Canal published revised "Rules, Regulations, and By Laws . . ." governing the operation of the waterway. Included in the document was the stipulation that "No boat or float shall be snubbed or fastened to the superstructure of the Wire Suspension Aqueducts . . . under a penalty of $10 for every violation."[4]

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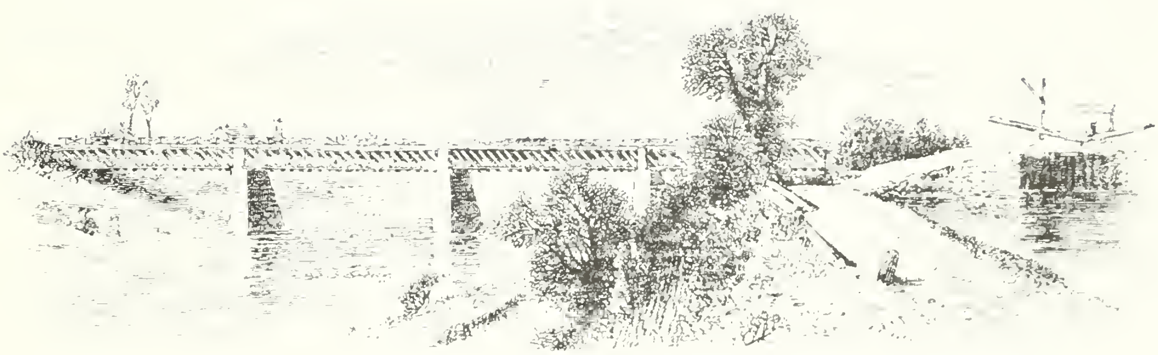
2. "Spot" McLaughlin, "A Trip Down the Canal," in "The D & H Canal: Stores, Etc.," Ellenville Public Library and Museum. Walter Wolfe, aged 98 and a long-time resident of the Barryville, New York, area, remembers taking a canal trip on a coal boat in 1896 at the age of 12. The boat was owned by his father and operated by his brother. Although he remembers passing over the Delaware Aqueduct, he does not remember anything noteworthy about the structure. Personal interview with Walter Wolfe, Narrowsburg, New York, May 3, 1983.

3. William Cullen Bryant, ed., Picturesque America . . ., 2 vols. (New York, 1874), II, 474, and P. L. Tucker, ed., The Erie Route: A Guide of the New York, Lake Erie & Western Railway and Its Branches. . . . (New York, 1887), p. 26.

4. "Rules, Regulations, and By Laws . . . of Delaware and Hudson Canal Co., March 30, 1853," printed in Delaware & Hudson Canal Co. against Penna. Coal Co., Exhibits, Exhibit FF.



William Cullen Bryant, ed., Picturesque America . . . 2 vols. (New York, 1874), II, 474.

A major flood on April 30, 1854, undermined the foundations of all the aqueducts along the line of the canal according to Chief Engineer Russel Lord. The height of the river came within 20 inches of the height of the ice flood of 1841.[5] No specific reference, however, was made to the Delaware Aqueduct. Thus, it can be presumed that the structure suffered no appreciable damage.

During the protracted legal proceedings between the Delaware and Hudson Canal Company and the Pennsylvania Coal Company during the late 1850s, Chief Engineer Lord was questioned in lengthy court sessions during December 1857 and January 1858 concerning the operation of the waterway. Included in his testimony was considerable data relative to the Delaware and Lackawaxen aqueducts. According to his testimony, the aqueducts had shortened the line of the canal by about one-half mile and the boating time saved by the two structures was "a day, or nearly a day in a round trip through the season." The trunks of the aqueducts were

> supported by a wire cable anchored back of the abutments on each side of the river, resting upon pyramids erected on the top of the abutments and piers; the trunk is built of timber and plank, attached to the wire cables, by which it is suspended between the bearings upon which it rests on the abutments and piers; there are two abutments to each aqueduct, three piers on the Delaware aqueduct and one in the Lackawaxen.

Only one boat could pass over an aqueduct at a time.[6]

Available documentation indicates that the Lackawaxen Aqueduct suffered considerably more damage than did the Delaware Aqueduct. According to the Annual Report of the Delaware and Hudson Canal

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5. Lord to Musgrave, January 23, 1855, Wakefield Collection, Delaware and Hudson Canal Historical Society.

6. Supreme Court, Ulster County, The President, Managers and Company of the Delaware and Hudson Canal Company, vs. The Pennsylvania Coal Company. Pleadings, and Testimony Taken Before J. H. Dubois, Referee, 7 vols. (New York, 1858), I, 179, 182, 184, 191, 218-19.

Company, 1863, a "freshet of unusual severity" in June 1862 "caused more or less damage to all the lines engaged in carrying Coal to tide water." The canal was "breached at several points, and one of its two principal Aqueducts--the one crossing the Lackawaxen--swept away. Six weeks of that part of the year most favorable for navigation--amounting practically to one-fourth of the whole season--were consumed in making necessary repairs, involving a very large outlay, and a loss of fully one-fifth of the estimated production of Coal. . . ."[7]

Some years later John Willard Johnston reminisced about the destruction of the Lackawaxen Aqueduct in June 1862. He noted:

> . . . by reason of heavy rains along the sources of the Lackawaxen River, that stream attained a height never before known to the memories of living man. The Delaware . . . was but slightly affected by the rains and, so great was the force of water issuing from the Lackawaxen that, it rushed quite across the Delaware and flooded up on the opposite shore. In the mad rush of water, the pier of the aqueduct spanning the Lackawaxen, was undermined, thrown down bodily, with but a single small crack, the use of the aqueduct destroyed and the entire business of the canal suspended for the time.[8]

The collapse of the center pier of the aqueduct left a large hole about 20 feet across and 10 feet deep in the pier's foundation. Chief Engineer Lord quickly erected a coffer dam around the hole and put six steam pumps into operation. Because of the leaking coffer dam, however, the water level was reduced by only 3 inches after nine days and the futile efforts of up to 100 men, including foremen, machinists, mechanics, and laborers. At that point Mr. Sykes, vice president of the canal company, arrived on the scene to direct the repair efforts. Johnston, who indicated that Lord's ineffectiveness was due to his intoxication, observed that Sykes

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7. Annual Report of the Delaware and Hudson Canal Company, 1863, p. 3, and Century of Progress, p. 179. The (Port Jervis) Union-Gazette carried an article on this event in its issue of June 1, 1973.

8. Johnston, "Reminiscences and Descriptive Account of the Delaware Valley," I, 143.

suggested that the cavity be filled by throwing in stones plentifully mingled with good cement mortar. That course was adopted; a thousand barrels of cement secured, and in 6 hours after the cement was at hand, the cavity was filled and the best foundation prepared. . . . In 8 days . . . the Aqueduct and the Canal was in working order. It is safe to estimate that the errors of a drunken man . . . cost the company not less than $300,000. . . .[9]

During the repair efforts John Roebling was contacted, and he sent an engineer who had been involved with the original construction of the aqueducts. After the engineer's return, Roebling, out of courtesy, congratulated Lord for repairing the aqueduct.[10]

In November 1863 the canal managers appropriated funds for doubling the size of the Neversink Aqueduct and the six Neversink locks to eliminate what was known as the "bottleneck" of the canal. Roebling was requested by Lord to prepare plans for the enlargement, but he asked the company to defer the project until after the termination of the Civil War. Later the idea was abandoned altogether because the increasing competition from railroads caused canal trade to decline.[11]

In 1867 the four aqueducts were described as "essentially permanent works, as merely the woodwork of the trunk requires occasional renewal."[12]

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9. Ibid., I, 143-45.

10. Roebling to Lord, July 11, 1862, Lord Collection, Minisink Valley Historical Society.

11. Olyphant to Lord, September 7, 1863, and Roebling to Lord, December 5, 1863, Lord Collection, Minisink Valley Historical Society; Booth, "Delaware and Hudson Canal," pp. 62-63; Century of Progress, p. 184; and Sullivan County Civil War Centennial Commission, Brass Buttons and Leather Boots (South Fallsburg, New York, 1963), p. 61.

12. "Mr. John A. Roebling," Engineering, 361.

There are references to a major break in the canal embankment in the vicinity of the Delaware and Lackawaxen aqueducts in August 1888, but there is no indication that the break caused damage to the structures. On the 26th an eighty-foot-wide break occurred in the bank of the canal "which separates it from the Delaware River at Lackawaxen." This sudden break caused considerable "damage to the coal-laden boats bound east" and took "some time to repair," thus causing "serious inconvenience" to the operation of the canal.[13]

The wooden flume and supporting timbers of the Delaware and Lackawaxen aqueducts were replaced periodically. The Tri-States Union reported on November 19, 1880, that the Lackawaxen Aqueduct and half of the Delaware Aqueduct would be rebuilt.[14] An item in the W. H. Nearpass Collection at the Minisink Valley Historical Society, dated March 22, 1897, noted that the Delaware Aqueduct had been repaired extensively.[15] Another item in the collection, dated March 5, 1898, contains the following:

> The new Aqueduct across the Delaware at Lackawaxen will soon be in readiness for use. Just after navigation closed last fall some three score men, mostly carpenters commenced tearing out the old planking and timbers and replacing them with new. As it is about seven hundred feet long and required half a million feet of lumber, some idea of the magnitude of the work may be imagined.[16]

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13. "A Break in the Delaware and Hudson Canal," Engineering and Building Record, XVIII (September 1, 1888), 158.

14. Tri-States Union, November 19, 1880, in Herman R. Lytell, "Story of the Delaware & Hudson Canal," p. 69 (typescript copy, Minisink Valley Historical Society).

15. W. H. Nearpass Collection, March 22, 1897, quoted in Lytell, "Story of the Delaware & Hudson Canal," pp. 69-70. Contemporary newspaper references cited in Booth, "Delaware and Hudson Canal," pp. 63-64, indicate that the wooden trunk or flume and supporting timbers were replaced on the Neversink Aqueduct during the winter of 1896-97.

16. W. H. Nearpass Collection, March 5, 1898, quoted in Lytell, "Story of the Delaware & Hudson Canal," pp. 70-71. A photograph of the Delaware Aqueduct taken ca. 1895 shows that the aqueduct had a number of major leaks. The photograph, which may be seen at the end of this report, is located in the collections of the Delaware and Hudson Canal Historical Society.

When the aqueduct was rebuilt in 1898 the timber was cut and fit at the canal lumber shop on the Lackawaxen side of the structure. The workers were paid seventy-five cents a day, and they labored from "sun up to sun down."[17]

The extensive program of canal improvements and enlargements of which the Delaware Aqueduct was an integral element enabled the canal company to compete successfully with the railroads for bulk coal haulage into the 1870s. By the mid-1850s more than 1,000,000 tons of coal were carried over the canal per year, and the company's profits were enormous, ranging from 10 to 24 percent net per annum on its already doubled capital. In 1847 arrangements had been made to lease part of its canal capacity to the Pennsylvania Coal Company, the tolls from whose boats, in addition to its own, swelled its coffers. By 1858 the canal company's railway was extended some seven miles farther down the Lackawanna Valley to reach other coal mines in the vicinity of Blakesly. During the 1860s northeastern Pennsylvania produced 40 to 50 percent of the entire anthracite supply for the United States, and the canal carried the greater share of it to tidewater. In 1864 the capital stock of the canal company was raised to $10,000,000, and even on this amount the net earnings of the following year were 31 percent.[18]

In December 1863 the Pennsylvania Coal Company completed a 6-foot gauge steam railroad from Hawley to a junction with the Erie Railroad at Lackawaxen, some 16 miles to the east. The loss of the business of the Pennsylvania Coal Company, which at its peak had comprised about half of the canal coal haulage, forced the Delaware and Hudson to begin serious planning for the construction and purchase of railroads itself, although the canal had nearly another decade of sustained growth in coal

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17. Jack Barnes, a long-time local resident of the upper Delaware Valley who is now deceased, gave these details to Carl A. Draxler. Personal interview with Carl A. Draxler, May 3, 1983.

18. Whitford, History of Canal System of New York, I, 749-50, and McDermott, Special Report, Delaware and Hudson Canal, p. 1.

transportation, reaching its peak load of 2,930,333 tons in 1872. Thereafter, the canal tonnage steadily declined as the Delaware and Hudson increasingly turned its attention to the acquisition and construction of railroads: the lease in perpetuity of the Albany and Susquehanna Railroad in February 1870 providing it new outlets in the north and east; absorption of the Rensselaer and Saratoga Railroad in May 1871; construction in 1875 of the New York and Canada Railroad on the west side of Lake Champlain; and building of a connecting link from Susquehanna, Pennsylvania, to Nineveh, New York, thus opening the Rochester and Buffalo markets to its products.[19]

The gradual diversion of more and more freight business from the canal to the railroads led to reduced profits for the canal operations. By 1897 only 250 boats were operating on the canal, down from the 1,400 that had once run during the canal's prosperous days. On October 26, 1898, a committee reported to the canal managers "that great economies would result from transporting the company's anthracite from the mines directly to the Hudson river and Weehawken by means of existing railroads instead of 'the present system of transportation by the Gravity railroad and canal.'" For some years a large proportion of coal mined by the Delaware and Hudson had been sent to New York over the Erie Railroad. Some 10 days later on November 5 the last canal boat was loaded and cleared at Honesdale. On February 23, 1899, the canal managers authorized abandonment of the canal, and on April 28 the New York state legislature authorized the managers to lease, sell, or discontinue the use of the canal whenever the transportation of the company's coal could be more economically accomplished by railroads. The legislature also sanctioned a change in the company's name to the Delaware and Hudson Company.[20]

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19. LeRoy, Delaware & Hudson Canal, pp. 67-69; Harlow, Old Towpaths, pp. 193-94; Whitford, History of Canal System of New York, I, 750-51; and Alfred Mathews, History of Wayne, Pike and Monroe Counties, Pennsylvania (Philadelphia, 1886), pp. 245-46.

20. Booth, "Delaware and Hudson Canal," pp. 80-81; Century of Progress, pp. 311-18; Editorial, Engineering News, XL (November 10, 1888), 296; LeRoy, Delaware & Hudson Canal, p. 83; and B. F. Fackenthal, Jr., "Improving Navigation on the Delaware River With Some Account of Its Ferries, Bridges, Canals and Floods," A Collection of Papers Read Before the Bucks County Historical Society, VI (1932), 196-200.

CHAPTER SEVEN
THE FATE OF THE LACKAWAXEN, NEVERSINK, AND HIGH FALLS AQUEDUCTS

The Lackawaxen, Neversink, and High Falls aqueducts all fell into general disuse and deterioration after the abandonment of the Delaware and Hudson Canal, largely because of their location in isolated areas.

The towpath of the Lackawaxen was used as a pedestrian crossing as late as the mid-1930s or perhaps the early 1940s.[1] Three photographs of the aqueduct dated April 16, 1935, in the Delaware and Hudson Railway Photograph Collection at the New York State Library show the trunk to be cluttered with debris and rotting and damaged timbers. Local residents recall using the towpath as a walkway and taking timbers out of the trunk to keep the towpath in repair. At some undetermined time in the late 1930s or early 1940s the trunk and supporting timbers were burned, and salvage dealers were permitted to cut up and remove the iron and metal components of the cable suspension system. Two stories have circulated about the removal of the masonry in the south abutment: (a) local residents helped themselves to the stone for personal use, and (b) the stone was removed and trucked to Port Jervis for use in the construction of a church. The north abutment was not removed because the local landowner would not permit its destruction. The pier in the center of the river was removed after Hurricane Diane in August 1955.[2]

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1. It is interesting to note that in December 1907 Pike County officials were considering the purchase of the Lackawaxen Aqueduct and converting it to use as a highway bridge. The alternative under consideration was construction of a new bridge near the mouth of the Lackawaxen at a cost of $10,000. Pike County Press, December 27, 1907.

2. Personal interviews with Edwin D. LeRoy, Easton, Pennsylvania, March 1, 1983; with Austin Smith, Barryville, New York, May 3, 1983; with Carl A. Draxler, May 3, 1983; and with Arthur H. and Annabel Haupt, May 4, 1983.

Nothing is known about the dismantling of the Neversink Aqueduct, but it is likely that it suffered a fate similar to that of the Lackawaxen. More is known, however, about the fate of the High Falls Aqueduct.

The structure over the Rondout was dismantled in August 1921. Undated photographs at the Delaware and Hudson Canal Historical Society in High Falls indicate that the trunk and supporting timbers had been destroyed by fire before that time.[3] When the cables and metal components were removed in 1921 samples of the wire were taken to John A. Roebling's Sons Company in Trenton, New Jersey, and tested. The tests performed on one of the wires, which according to Roebling's records had a tensile strength of 90,000 pounds per square inch, were as follows:

Diameter	0.153 in.
Breaking strength	1.753 lb.
Ultimate strength	94,166 lb. per sq. in.
Reduction of area	25.4 per cent

According to H. C. Boynton, a metallurgist with John A. Roebling's Sons, the wire samples were "not galvanized or coated with any metal, yet the corrosion of this wire, while marked, was not excessive. There was relatively little pitting of the surface." Boynton concluded:

> . . . this proves quite conclusively . . . that old wrought iron made 75 years ago is much more resistant to corrosion from ordinary weathering than our present high carbon steel made in acid open-hearth furnaces under strictest supervision.
>
> . . . it certainly seems apparent that the cold-worked iron installed 75 years ago has not lost its valuable physical properties since the bridge was erected. In fact, the general opinion among my associates here is that cold-drawn wire gradually grows a little stronger with age. . . .[4]

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3. In his Roebling's Delaware & Hudson Canal Aqueducts, p. 29, Vogel states that the fire occurred about 1916.

4. H. C. Boynton, "Bridge Wire Tested After 75 Years," The Iron Age, CXXI (February 9, 1928), 400.

CHAPTER EIGHT
THE DELAWARE AQUEDUCT UNDER THE CORNELL STEAMBOAT COMPANY: 1899

Following the abandonment of the canal the Delaware and Hudson Company began to look for prospective buyers of the former waterway. Potential purchasers included the New York, Ontario and Western Railway Company, the Pennsylvania Coal Company, and the Erie Railroad Company, and negotiations were attempted with those corporations. After some months the Delaware and Hudson conveyed the canal "with all its franchises, rights and privileges" to the Cornell Steamboat Company for $10,000 by a deed dated June 24, 1899. The deed stipulated that the conveyance included the entire line of the canal "excepting such part as the Delaware and Hudson Company may wish to sell or use" and that the transfer was made with the understanding that the canal "shall be maintained as such."[1]

The Cornell Steamboat Company, whose president and principal owner was Samuel D. Coykendall of Kingston, New York, had operated under contract the Hudson River towing services for the Delaware and Hudson Canal Company for some years. Coykendall was involved with the Ulster and Delaware Railroad and was referred to as a "railroad and steamboat magnate."[2] There were numerous well-founded rumors in Delaware Valley and northeastern Pennsylvania newspapers that he was fronting for various railway interests when purchasing the canal. According to The Wayne Independent of June 28, 1899, Coykendall

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1. Deed, Delaware and Hudson Company to Cornell Steamboat Company, dated June 24, 1899, Orange County Deed Book 453, Folio 63, as quoted in Booth, "Delaware and Hudson Canal," p. 81, and Century of Progress, p. 317.

2. The Cornell Steamboat Company was apparently a Coykendall family enterprise since its vice president was George Coykendall and its secretary was Frederick Coykendall.

> and the [Delaware and Hudson] Company are on very friendly terms and it is only recently he started to extend his Ulster and Delaware road to Oneonta, where it connects with the Delaware & Hudson, and the coal of the latter road will find its way to Kingston by means of this connection. For the past week a corps of engineers and surveyors had been locating and surveying a route on the Moosic mountains. The company secured options for the line some months ago, and by following the canal in part it will afford a short route to tide water, as well as easy grades.

The article also noted that the Vanderbilt-Morgan interests were attempting to acquire the Delaware and Hudson railroad system as part of their attempt to establish a transcontinental railroad.[3]

The railroad scheme of the Vanderbilt-Morgan interests was spelled out more clearly in The Wayne Independent on July 5. The paper reported:

> The D & H officials when interviewed here and elsewhere, have not denied that a great railroad project is in store for Honesdale. The Vanderbilt and Morgan plan to get hold of the D & H system is said to be identical with that used in securing control of the Boston & Albany and the Fitchburg lines. They are after every feeder they can acquire for their proposed great transcontinental road. The anthractite carrying roads are all coming under their control, the D & H. and Erie being the only ones left. This began with the change of management in the Del, Lack & West. over a year ago. Since then the canal and Gravity road have been abandoned and the coal for the eastern market has been hauled northward to Albany, hundreds of miles out of the way. This, it is plain to be seen, is being done at a loss and a more direct line to the seaboard and to the east must be utilized. The only route is through Honesdale. Then the handling of coal is not the only object the Morgan and Vanderbilt people have in view . . . they want the passenger and freight traffic of the great anthracite coal regions for their proposed trunk line between the east and the west. . . . The Vanderbilts have greatly increased their holdings in Delaware & Hudson and . . . they are now in a position to carry out their

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3. The Wayne Independent, June 28, 1899. Also see Milford Dispatch, June 29, 1899. The proposed Vanderbilt-Morgan system would also include the following railroads: Boston & Albany; New York, New Haven and Hartford; New York Central; Lake Shore, Chicago and Northwestern; and Union Pacific.

plan of several years ago to bring the system under the management of New York Central, under terms very similar to those offered to Boston & Albany. . . .[4]

There is no documentation relative to the use of the Delaware Aqueduct during the five- to six-month period that it was owned by the Cornell Steamboat Company. Local area residents, however, undoubtedly used the aqueduct to cross the river. Local tradition has it that once the canal was abandoned some buggies even crossed the Delaware on the former towpaths of the aqueducts with one wheel on the planking and the other on the guard rail.[5]

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4. The Wayne Independent, July 5, 1899.

5. Personal interviews with Orson Davis, Minisink Ford, New York, May 5, 1983; with Arthur H. and Annabel Haupt, May 4, 1983; and with Carl A. Draxler, May 3, 1983.

CHAPTER NINE
THE DELAWARE AQUEDUCT UNDER THE ERIE AND WYOMING VALLEY AND THE DELAWARE VALLEY AND KINGSTON RAILROAD COMPANIES: 1899-1908

In November and December 1899 the Cornell Steamboat Company lent credence to the "railroad scheme" rumors by conveying the Pennsylvania side of the Delaware Aqueduct to the Erie and Wyoming Valley Railroad and the New York side to the Delaware Valley and Kingston Railroad respectively. On November 11 a parcel of land on the Pennsylvania side of the aqueduct with the following boundary description was conveyed to the Erie and Wyoming Valley Railroad for "one dollar and other valuable considerations":

> . . . All that tract or parcel of land situate in the township of Lackawaxen, County of Pike and State of Pennsylvania consisting of a strip of land thirty (30) feet wide, bounded easterly by the westerly end of the aqueduct formerly carrying the Delaware & Hudson Canal over the Delaware River and known as the Delaware & Hudson Aqueduct; bounded westerly by . . . a line drawn parallel with and distant fifteen (15) feet westerly from the Delaware & Hudson Canal, and bounded northerly and southerly by lines drawn parallel with and distant fifteen (15) feet (measured at right angles) northerly and southerly, respectively, from a line which would be a westerly extension of the center line of said aqueduct, together with so much of the Delaware & Hudson Canal aqueduct aforesaid as now constructed and existing across the Delaware River from a point in the town of Highland, in the County of Sullivan and State of New York, to a point in the said Township of Lackawaxen and State of Pennsylvania, together with the side roadways attached thereto, and forming a part of said portion of said structure, and the wire cables, archorages, supports, masonry, piers and abutments supporting said portion of said structure, and all other appurtenances thereof; together with the land adjacent to the river occupied by said portion of said structure and its appurtenances, and any and all rights, franchises and easements to operate and maintain the said aqueduct and its appurtenances across and over said river . . . said premises being hereby conveyed subject to all the

> covenants and conditions contained in said deed [deed from Delaware and Hudson Company to Cornell Steamboat Company]. . . .[1]

One month later on December 11 the Cornell Steamboat Company conveyed the line of the canal from the New York-Pennsylvania border to Huguenot, New York, to the Delaware Valley and Kingston Railway for the sum of "one dollar and other valuable considerations." This tract, which included the New York side of the Delaware Aqueduct, had the following boundaries:

> All that portion of the Delaware and Hudson Canal situated in the State of New York which commences at the boundary line between the States of New York and Pennsylvania at or opposite the borough of Lackawaxen, Pike County, Pennsylvania, and ends at the westerly lock at or near the Village of Huguenot in the County of Orange, State of New York, with all the aqueducts, bridges, property, rights, franchises and easements, appurtenant thereto, including the canal bed, locks and their appurtenances, tow-path, rights to divert and use water for canal purposes from the Neversink and Delaware Rivers, so long as said canal shall be maintained as such; also a strip of land fifteen feet wide on each side of the said canal, wherever the Delaware and Hudson Company prior to the conveyance by it hereinafter mentioned had title to such land, excepting and reserving such parts thereof if any as were excepted and reserved to the said Delaware and Hudson Company by the said deed of conveyance: being a said portion of the said canal and its appurtenances, situated in the State of New York, heretofore conveyed to the party of the first part by the said Delaware and Hudson Company, by an instrument dated June 24, 1899, together with all the estate and rights of the party of the first part and of the Delaware and Hudson Company in all to the premises aforesaid: and also all the rights and franchises of every kind owned, possessed, used or enjoyed by the party of the first part or formerly owned, possessed, used or enjoyed by the said Delaware and Hudson Company in connection with the ownership use and operation of

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1. Deed, Cornell Steamboat Company to Erie and Wyoming Valley Railroad, dated November 11, 1899, as alluded to and described in Deed, Erie and Wyoming Valley Railroad to Charles Spruks, dated May 12, 1908, Pike County Deed Book 62, Folios 351-53.

said canal or otherwise not including, however, any lands and buildings not above described.[2]

The sale of the two sides of the Delaware Aqueduct to the two railroad companies was part of the railroad scheme and political maneuvering referred to earlier when the Delaware and Hudson Canal was sold to the Cornell Steamboat Company. The Wayne Independent of November 15 and December 13, 1899, provided clues as to the intricate dealings surrounding the sale of the aqueduct:

> Behind the incorporation, on February last, at Albany of the Delaware Valley and Kingston Railroad Company stands the rich and influential Pennsylvania Coal Company, which has for years been forced to share its profits with J. Pierpont Morgan's road, the Erie, under a traffic agreement compulsory upon the coal company in order to distribute its product.

Since the Pennsylvania Coal Company desired to end that arrangement, it was proposing "to build a railroad 81 miles long from a point within 10 miles of Lackawaxen . . . to Kingston." The first step had been to purchase

> the old abandoned D & H canal, which follows the line of the proposed new road. . . .
>
> The Pennsylvania Coal Company owns the Erie and Wyoming Valley road, which taps the coal region at several points and which, under the traffic arrangement with the Erie, has been operated by that company. One of the branches of this road runs to Lackawaxen.
>
> The newly incorporated Delaware Valley and Kingston Railroad Company will first construct its 81 miles of line to Kingston. The Pennsylvania Coal Company will extend its line from Lackawaxen to join the new road, and will then have a complete independent line from the coal fields to tidewater. . . .

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2. Deed, Cornell Steamboat Company to Delaware Valley and Kingston Railway Company, dated December 11, 1899, Sullivan County Deed Book 133, Folios 87-90. At the same time the Cornell Steamboat Company conveyed the section of canal between Huguenot and Summitville to the Delaware Valley and Kingston Railway. Deed, Cornell Steamboat Company to Delaware Valley and Kingston Railway Company, dated December 11, 1899, Orange County Deed Book 459, Folio 355, as quoted in Booth, "Delaware and Hudson Canal," p. 81.

> The building of a railroad on the line of the abandoned D & H canal verifies the oft predicted yet as frequently denied statement that such a project has for some time been on foot. . . .
>
> For sometime the Erie & Wyoming company have been straightening the curves and double-tracking their road. This line is owned and [sic] is also the road between Hawley and Lackawaxen by the Pennsylvania Coal Company. Surveyors have already commenced work along the canal below Hawley and it is presumed that the second tract for the road is to be laid on the canal side of the Lackawaxen.
>
> Just what the Erie people will now do is a matter of conjecture. The company owns the ten miles of road between Honesdale and Hawley and whether they will continue to lease track privileges of the Pennsylvania Coal company or build a new line from Mast Hope to Honesdale and from this point up the Dyberry, or Lackawaxen, remains to be told.
>
> A complete map of the new Delaware Valley and Kingston railroad to be built from this city [Kingston] to Lackawaxen, Pa., was filed in the Ulster county Clerk's office . . . by Judge Clearwater, counsel for Samuel D. Coykendall, president of the Cornell Steamboat Company. It is expected that this new road will revolutionize the coal traffic between the Pennsylvania coal fields and New England. . . . Mr. Coykendall purchased all the real estate owned by the D & H Canal Company on both sides of Rondout Creek [between Kingston and Eddyville] for $160,000. He purchased the entire canal itself in February [June] last, which gave rise at that time to the rumor of the present railway project. It is intended to prosecute the work of constructing the road as rapidly as possible.[3]

In light of this data it is important that the background of the Erie and Wyoming Valley and the Delaware Valley and Kingston Railroads be examined. Organized on November 6, 1882, by a group of financiers and capitalists from Scranton, Wilkes-Barre, and Reading, the Erie and Wyoming Valley Railroad built a railway that extended by 1891 from the Lackawaxen River in Pike County to Port Griffith in Luzerne County, thus making a connection between the Delaware and Susquehanna Rivers. The road from Lackawaxen to Hawley, a distance of 16 miles, was leased to the New York, Lake Erie & Western Railroad Company and was

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3. The Wayne Independent, November 15, December 13, 1899.

operated by that company. From Hawley to Port Griffith, a distance of 48 miles, the line was operated by the Erie & Wyoming Valley Railroad. There were a number of branches to this road: from Dunmore to Scranton, a distance of three miles, and several to the breakers of the Pennsylvania Coal Company and those of other operators located along the main line--an aggregate of eight miles. The road made connections with the New York, Lake Erie & Western at Hawley, the Delaware, Lackawanna & Western and the Delaware & Hudson Company's railroad at Scranton, the Bloomsburg Division of the Delaware, Lackawanna & Western Railroad at Avoca, and the Lehigh Valley Railroad at the Lackawanna & Bloomsburg Junction.[4]

Early in 1899 officers of the Delaware and Hudson Company organized the Delaware Valley and Kingston Railroad under the leadership of Samuel D. Coykendall for the expressed purpose of constructing a railroad along the bed of the Delaware and Hudson Canal from Kingston to Lackawaxen, there to connect with the Pennsylvania Coal Company's Erie and Wyoming Valley Railroad and thus deprive the Erie Railroad of the coal company's traffic. Acting quickly to defeat this scheme the Erie by 1901 had completed arrangements to purchase outright the railroad property of the Pennsylvania Coal Company which it had operated under a lease agreement. As a further safeguard the Erie bought the right-of-way of the canal in the Lackawaxen vicinity, thus preventing any competitor from building over a parallel route.[5]

While the Erie Railroad thwarted the prospective line of the Delaware Valley and Kingston Railroad at Lackawaxen, there was further resistance to such a line by other railroad interests between Ellenville and Kingston. In 1899 and 1900 the Rondout Valley Railway Company, which later became the Ontario and Western Railroad, was planning to build a line from

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4. H. W. Crew, History of Scranton, Penn. (Dayton, Ohio, 1891), pp. 354-55.

5. LeRoy, Delaware & Hudson Canal, p. 83, and Booth, "Delaware and Hudson Canal," pp. 81-82.

Ellenville to Kingston which involved crossing the former canal. Resistance to such a line developed quickly and as a result the canal was described as looking "like a Boer War entrenchment." The Cornell Steamboat Company flooded the canal and drew up two smoothbore cannon, and it was reported that "watchmen day and night are kept on duty with instructions to blow to smitherines anyone who attempts to throw a bridge across the canal." By June 7, 1901, however, the Ontario and Western had purchased from the Cornell Steamboat Company the 25-mile stretch of the former canal between Summitville and Alligerville and proceeded to extend its road from Ellenville to Kingston under the name of the Ellenville and Kingston Railroad. The road was surveyed to follow the canal from Ellenville to Alligerville and thence along a line already run through Stone Ridge to Kingston. The new line was used primarily for the summer tourist resort business.[6]

During the 1899-1908 period that the two sides of the Delaware Aqueduct were in the hands of the railroad interests, it is likely that the structure primarily served informal local cross-river transportation needs. While it has been generally assumed that the aqueduct was converted to use as a highway bridge and the toll house constructed on the New York side of the bridge during the years 1899-1901, this conclusion is somewhat unlikely in view of the inter-railroad rivalry. Moreover, a newspaper clipping dated May 22, 1901, describes the condition of the former canal as follows: "The feeders are abandoned, the canal is dry, . . . the aqueducts are wrecks. . . ."[7]

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6. Manville B. Wakefield, To the Mountains By Rail (Grahamsville, New York, 1970), pp. 63-67, 394.

7. Unidentified newspaper clipping, May 22, 1902, "Delaware and Hudson Canal," Vertical Files, Pike County Historical Society, Milford, Pennsylvania.

CHAPTER TEN
THE DELAWARE AQUEDUCT UNDER CHARLES SPRUKS: 1908-30

After nearly eight years during which the two sides of the Delaware Aqueduct were in the hands of railroad interests, the entire structure and its approaches became the property of Charles Spruks, a Scranton lumber dealer who specialized in the heavy timbers used as supports in the area's coal mines. On May 12, 1908, Spruks purchased for $1 and other considerations the tract that the Erie and Wyoming Valley Railroad Company had bought from the Cornell Steamboat Company in November 1899. The interesting aspect of this deed is that it is accompanied by a map, a copy of which may be seen on the following page.[1]

That same day Spruks purchased the New York side of the aqueduct and approaches from the Delaware Valley and Kingston Railway Company for $1 and other considerations. This parcel, which was only a small portion of the large tract that had been conveyed to the railroad by the Cornell Steamboat Company in December 1899, was bounded as follows:

> All that tract or parcel of land situate in the Town of Highland, County of Sullivan and State of New York, consisting of a strip of land thirty (30) feet wide, bounded westeriy by the easterly end of the aqueduct formerly carrying the Delaware & Hudson Canal over the Delaware River and known as the Delaware & Hudson Canal Aqueduct; bounded easterly by the easterly line of lands of said party of the first part, which is a line drawn parallel with and distant fifteen (15) feet easterly from the Delaware & Hudson Canal, and bounded northerly and southerly by lines drawn parallel with and distant fifteen (15) feet (measured at right angles) northerly and southerly respectively, from a line which would be an easterly extension of the center line of said aqueduct; together with so much of the Delaware & Hudson Canal Aqueduct aforesaid as now constructed and existing across the Delaware River from a point in said Town of Highland to a point in the Township of Lackawaxen, County of Pike and State of Pennsylvania, as is

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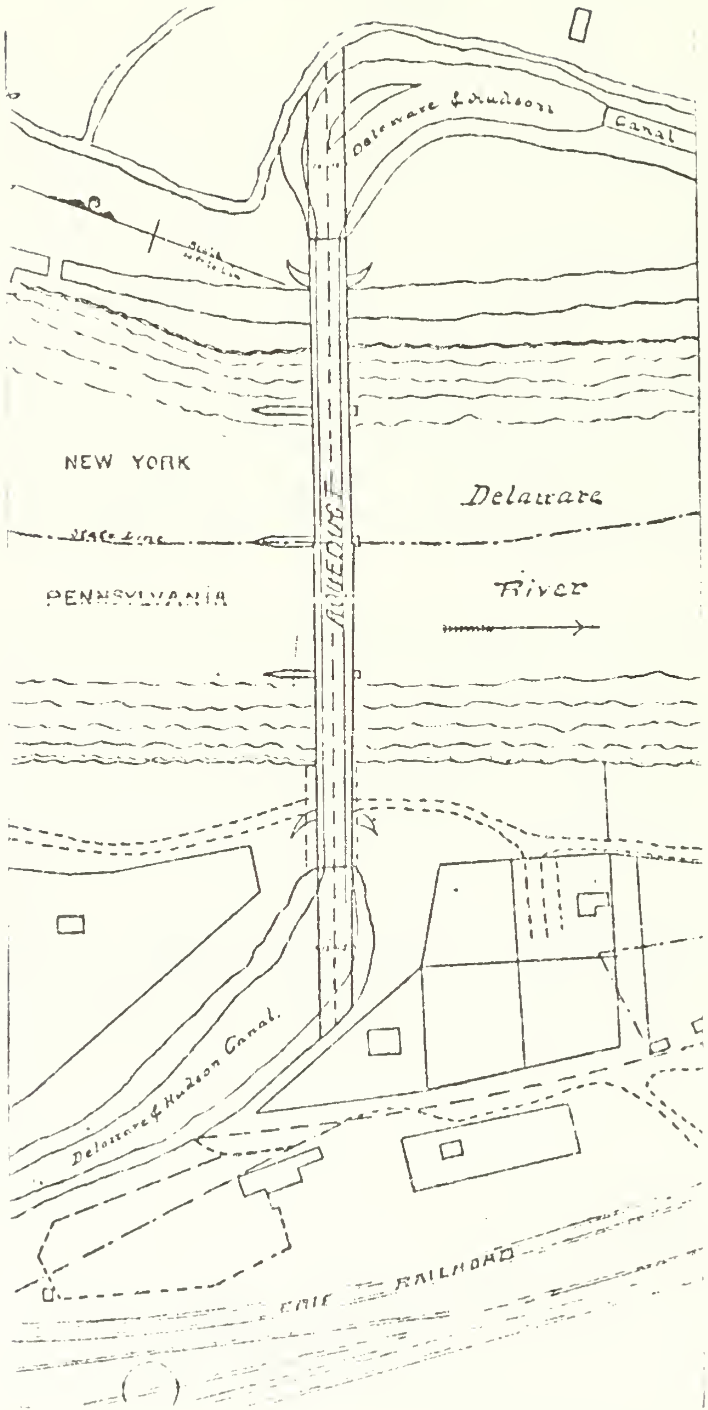
1. Deed, Erie and Wyoming Valley Railroad Company to Charles Spruks, dated May 12, 1908, Pike County Deed Book 62, Folios 351-53.


Delaware & Hudson
Canal
NEW YORK
Delaware
State Line
AQUEDUCT
PENNSYLVANIA
River
Delaware & Hudson Canal.
ERIE RAILROAD

> located in said town of Highland and State of New York; together with the side roadways attached thereto and forming a part of said portion of said structure, and the wire cables, anchorages, supports, masonry piers, and abutments supporting said portion of said structure, and all other appurtenances thereof; together with the land adjacent to the river occupied by said portion of said structure and its appurtenances, and any and all rights, franchises and easements to operate and maintain the said aqueduct and its appurtenances across and over said river. . . .[2]

Charles Spruks was the son of John Spruks, Jr., who had learned the carpenter's trade in Germany and in 1842 had emigrated to the United States at the age of 18, settling on Staten Island where he married. Later, he branched out into building contracting and bought a farm at Beach Lake in Wayne County, Pennsylvania. In 1886 two of John's sons, Henry J. and Thomas, formed the firm of Spruks Brothers, a large lumber yard and building contracting concern in Scranton. Among other structures the firm had built two schoolhouses, the Scranton axle factory, the Lutheran and Polish churches, and some of the city's most fashionable residences by 1897. The two brothers also purchased two blocks along the main line of the Erie Railroad, where they erected sheds for their retail coal business operated under the firm name of Spruks & Gibbons. They, along with their brother Stephen S., were involved with a variety of other business interests: the Scranton axle works; the Allegheny Lumber Company, operating in North Carolina; and the Eureka Lumber Company in Washington, North Carolina, which manufactured yellow pine and cypress lumber. Charles, the second youngest of John's ten children, began his business career by serving as a bookkeeper for his brothers and was active in that capacity by 1897.[3]

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2. Deed, Delaware Valley and Kingston Railway Company to Charles Spruks, dated May 12, 1908, Sullivan County Deed Book 155, Folios 48-49.

3. Portrait and Biographical Record of Lackawanna County, Pennsylvania (New York, 1897), pp. 278-79, and Frederick L. Hitchcock, History of Scranton and Its People, 2 vols. (New York, 1914), II, 345-46.

During the early 1900s Charles Spruks apparently acquired extensive timber holdings in Sullivan County, New York, along with several other lumber contractors from Pond Eddy with the goal of specializing in the heavy timbers used as supports in the coal mines of northeastern Pennsylvania. Thus, he purchased the Delaware Aqueduct primarily to afford a simple means of getting the logs across the Delaware to the railhead in Lackawaxen. As a sideline he apparently built a toll house and swinging lattice-work gate on the New York side of the aqueduct to collect tolls from common-road traffic. During this period the towpaths were sawn off the aqueduct, a low railing was run along the downstream side of the trunk floor to provide a separated pedèstrian walk, and some grading was done at each end for access to existing roads.[4]

The Delaware Aqueduct received publicity in a national periodical as early as August 1914 when Edward Hungerford commented on its significance in an article in Harper's Magazine. He observed:

> At the upper end of the old Delaware & Hudson one monumental landmark still remains--the erstwhile aqueduct across the Delaware. . . . It is a sturdy wooden structure, wondrously fashioned. For sixty-five years it has defied the fearful springtime floods down the Delaware--floods that have played havoc with more modern and elaborate bridges. Today it is itself a highway bridge of importance. And where the slow-moving coal-barges once made their weary way the automobile has quick and easy flight.[5]

In 1926 Alvin F. Harlow published his Old Towpaths, a widely-read history of the American canal era. In this work he observed that the four Roebling aqueducts on the Delaware and Hudson Canal

> not only stood until the canal's abandonment without giving away or sagging, but the one which spans the Delaware is in use to-day as a highway bridge; and the opinion was recently

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4. Vogel, Roebling's Delaware & Hudson Canal Aqueducts, p. 25. Also see Fackenthal, "Improving Navigation on the Delaware River," p. 198.

5. Edward Hungerford, "Visions of Old Waterways," Harper's Magazine, CXXIX (August, 1914), 399.

expressed that if the canal were to be put in service again, the wood-work of the aqueduct might have to be replaced, but the cables and anchorages are so sound that they would support the weight of the water and boats again, just as they did eighty years ago.[6]

Much of the story of the maintenance and operation of the Delaware Aqueduct during its twenty-two-year ownership by Spruks is based on personal interviews with long-time residents of the area. Edwin D. LeRoy, the author of The Delaware & Hudson Canal and It's Gravity Railroads, remembers passing across the bridge with a horse and wagon for the first time around 1914. Since there were no paved roads in the surrounding counties until the late 1920s and there were few automobiles in the area, much of the traffic in those early years consisted of horse-drawn farm wagons according to LeRoy. Maintenance of the bridge consisted primarily of "touch & go" operations that were designed to meet whatever needs were apparent to keep the bridge open for transportation.[7] Austin Smith, currently town historian of Highland, New York, remembers chaufferring a doctor over the bridge as a youth during the early 1920s by automobile. Barbara Nieke, the part-time fill-in toll keeper at the bridge for many years, informed the doctor that he would have to buy another booklet of bridge tickets (ticket books were sold at the toll house) when he attempted to have Smith pass through the toll gate without paying.[8] Barbara Nieke, who occasionally worked as a toll keeper at the bridge during the 1920s, remembers numerous horse-drawn wagons carrying logs and stone across the span during that period.[9]

Considerable information on the Spruks period of ownership was provided by Carl A. Draxler, a resident of the Minisink Ford area since

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6. Harlow, Old Towpaths, p. 306.

7. Personal interview with Edwin D. LeRoy, March 1, 1983.

8. Personal interview with Austin Smith, Barryville, New York, May 3, 1983.

9. Personal interview with Barbara Nieke, Minisink Ford, New York, May 5, 1983.

1920, and Arthur H. and Annabel Haupt, residents of Lackawaxen for more than 65 years. During much of Spruks' ownership Andy Paye, one of Spruks' partners from Pond Eddy, served as bridge overseer. Alonzo Smith, who had worked as a maintenance man for local Lackawaxen boarding houses, served as the toll collector during the 1910s and 1920s, living in the toll house with his wife and daughter. The kitchen and one bedroom were downstairs, and a bedroom and living room were upstairs. Annabel Haupt, who has lived in Lackawaxen all her life, was a friend of Smith's daughter and took piano lessons in the toll house living room in 1911-12 from a teacher from Port Jervis. Zane Grey, a favorite with the children during the early 1900s because he took them for buggy rides on the former canal towpath and held annual parties for them on Washington's Birthday at his Lackawaxen home, owned property near Minisink Battlefield and thus used the toll bridge to "keep an eye on his property."

During the early 1920s Ella, Bob, and Court Campbell lived in the toll house and collected tolls for Spruks. Ella smoked a pipe and used Yellow Daisy tobacco--thus her nickname was Yellow Daisy. The bridge was open from about 7 a.m. to 8 or 9 p.m. The tolls were collected through a window in the kitchen downstairs, and records were kept on a pad of paper in the kitchen. The large gate across the roadway would be raised after the toll was paid. A smaller gate was located closer to the toll house to allow pedestrians to pass. In those days the toll for a pedestrian was 2¢ while that for walking a cow or pig over the bridge was 3¢. In the earthen enbankment across the entry road to the bridge Ella Campbell maintained a timber-lined and supported root cellar, consisting of two rooms with wooden ventilators and shelves on both sides of a center aisle, in which she sold groceries, meat, and produce.

During the 1910s and 1920s the Delaware Aqueduct was used extensively for haulage of railroad ties and mine props to the railroad yard at Lackawaxen. Double teams of horses were often needed to take the loads up the steep grade on the Pennsylvania side of the bridge. Among the most active lumber dealers who used the aqueduct were John

R. Redding, Ben Campbell, Michael Clark, Theodore Kunkell, Adam Eichman, Arthur Barnes, Peter Kessler, and Louis Wizlanchis.[10]

During the 1920s Spruks made several small purchases of property to add to his holdings at the Delaware Aqueduct. In September 1921 he bought a small parcel of land, totaling .05 of an acre, on the Pennsylvania side of the aqueduct which had become popularly known as the Highland and Lackawaxen Bridge. The land was purchased from William C. and Jerusha W. Cortright of Lackawaxen for the sum of $1. This parcel which Spruks had used as an approach from the highway to the bridge at Lackawaxen since 1908, had the following boundary description:

> ALL TRACT OR PARCEL OF LAND, situate, lying and being in the Township of Lackawaxen, County of Pike and State of Pennsylvania and bounded and described as follows: BEGINNING at a point formed by the intersection of a line parallel to the abandoned Delaware and Hudson Canal and distant fifteen feet Southerly from the berme side of same and the property line of said William C. Cortright and one Anna C. Gregory; and running thence North 39 degrees West forty-one links to Southeasterly edge of a small stone retaining wall; thence South 48-1/4 degrees West one chain and sixty-one links along edge of said wall to the center of the highway leading from the Lackawaxen Post Office past the residence of said William C. Cortright; thence along center of said highway South 24-1/4 degrees East twenty-five links; thence North 54-1/4 degrees East one chain and sixty-eight links along lands of said Anna C. Gregory to place of beginning.[11]

Later on November 11, 1929, Spruks purchased an additional .75-acre parcel on the New York side of the bridge from Louise Ernst of

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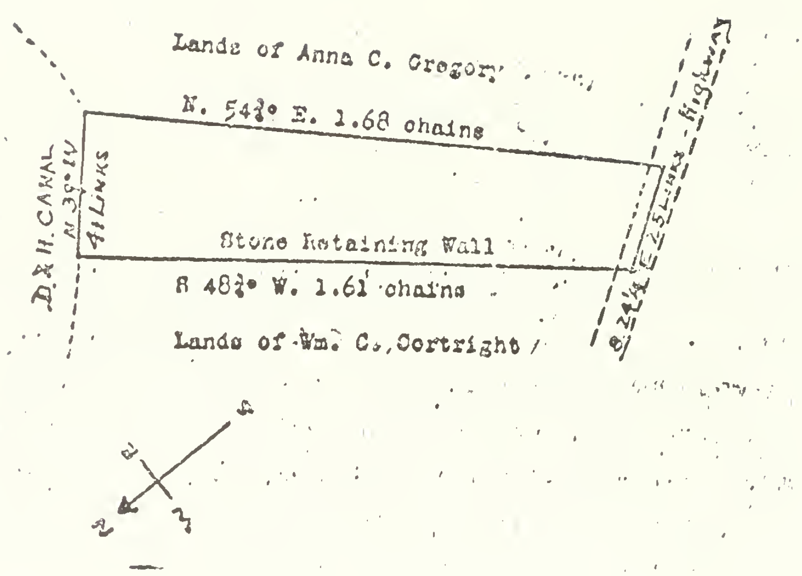
10. Personal interviews with Carl A. Draxler, May 3, 1982, and Arthur H. and Annabel Haupt, May 4, 1983.

11. Deed, William C. Cortright and Jerusha W. Cortright to Charles Spruks, dated September 13, 1921, Pike County Deed Book 73, Folios 305-06. A small map accompanies this deed, a copy of which may be seen on the following page.


Lands of Anna C. Gregory
N. 54¾° E. 1.68 chains
D. & H. CANAL
N 39° 10
41 LINKS
Stone Retaining Wall
S 48¾° W. 1.61 chains
Lands of Wm. C. Cortright
25 LINKS
Highway

Minisink Ford, New York, and Paulina Diem of Lackawaxen, Pennsylvania, paying them each $1 for the property. The parcel had the following boundary description:

> All that Piece or Parcel of land, situate lying or being in the town of Highland, County of Sullivan and State of New York bounded and described as follows: Beginning at a point in the highway leading across the Delaware River to the hamlet of Lackawaxen, Pa., said point being 3. 65° 19' E. 19.0 feet from transit point No. 1 of the March 1921 survey, which transit point is on the center line of the bridge; 39.5 feet from the northeasterly corner of toll house; 32.05 feet from wall at the end of building just east of toll house, 33.5 feet from opposite end of wall and 21.2 feet from the south westerly corner of building opposite end of bridge.
>
> From the place of beginning S. 27° 27' E. 35.0 feet; thence S. 62° 33' W. 65 feet, then S. 27° 27' E. 22 feet; thence S. 62° 33' W. 142 feet more or less to the edge of Delaware River thence along the edge of the Delaware River N. 27° 27' W. 145 feet; thence N. 62° 33' E. 1930 feet more or less, thence S. 73° 10' E. 20.44 feet, thence S. 27° 27' E. 15 feet and thence S. 62° 33' W. 110.17 feet to the place of beginning.[12]

12. Deed, Louise Ernst to Charles Spruks, dated November 22, 1929, and Deed, Paulina Diem to Charles Spruks, dated November 22, 1929, Sullivan County Deed Book 275, Folios 315-17 and 317-18, respectively.

CHAPTER ELEVEN

THE DELAWARE AQUEDUCT UNDER THE LACKAWAXEN BRIDGE COMPANY (FEDERAL BRIDGE COMPANY, OWNER): 1930-42

The Delaware Aqueduct was sold by Charles Spruks to the Lackawaxen Bridge Company on November 1, 1930. The Lackawaxen Bridge Company, which had been incorporated in the State of Delaware on January 10, 1930, with 100 shares of stock, was a subsidiary of the Federal Bridge Company, a toll bridge holding company with offices in New York City. Under the leadership of its president, Col. Peter K. Schuyler, a retired Army officer, the Federal Bridge Company owned or leased four highway toll bridges as of November 1, 1930.[1]

Spruks conveyed two Pike County and two Sullivan County parcels of land containing the aqueduct and its approaches to the Lackawaxen Bridge Company on November 1, 1930, for the sum of $3 and other considerations. The Pike County parcels had the following boundaries:

> 1. ALL THAT TRACT OR PARCEL OF LAND situated in the Township of Lackawaxen, County of Pike and State of Pennsylvania, consisting of a strip of land thirty (30) feet wide, bounded easterly by the westerly end of the aqueduct, formerly carrying the Delaware & Hudson Canal over the Delaware River and known as the Delaware and Hudson Aqueduct; bounded westerly by a line, described in deed of Erie and Wyoming Valley Railroad Company to Charles Spruks dated May 12th, 1908 as "the westerly line of lands of said party of the first part," which is a line drawn parallel with and distant fifteen (15) feet westerly from the Delaware & Hudson Canal, and bounded Northerly and Southerly by lines drawn parallel with and distant fifteen (15) feet (measured at right

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1. New York Times, October 22, 1930; P. K. Schuyler, "Lackawaxen Suspension Bridge Rebuilt for Present-Day Use," Engineering and Contracting, LXIX (November, 1930), 421; and Vogel, Roebling's Delaware & Hudson Canal Aqueducts, p. 26. One of the four toll bridges was the Reno Toll Bridge at Oil City, Pennsylvania, which the Federal Bridge Company leased for a period of the Delaware Aqueduct. The Lackawaxen Bridge Company pledged a mortgage of $35,000 to Charles Spruks as part of the transaction.

angles) northerly and southerly respectively, from a line which would be a westerly extension of the center line of said aqueduct, together with so much of the Delaware & Hudson Canal aqueduct aforesaid as now constructed and existing across the Delaware River from a point in the Town of Highland, in the County of Sullivan and State of New York, to a point in the said Township of Lackawaxen, as is located in said Township of Lackawaxen and State of Pennsylvania; together with the side roadways attached thereto and forming a part of said portion of said structure, and the wire cables, anchorages, supports, masonry, piers and abutments supporting said portion of said structure, and all other appurtenances therefore; together with the land adjacent to the river occupied by said portion of said structure and its appurtenances, and any and all rights, franchises and easements to operate and maintain the said aqueduct and its appurtenances across and over the said river. . . .

2. ALL THAT TRACT OR PARCEL OF LAND, situated, lying and being in the Township of Lackawaxen, County of Pike and State of Pennsylvania and bounded and described as follows: BEGINNING at a point formed by the intersection of a line parallel to the abandoned Delaware and Hudson Canal and distant fifteen feet Southerly from the berme side of same and the property line of said William C. Courtright and One Anna C. Gregory and running thence North 39 degrees and West forty-one links to Southeasterly edge of a small stone retaining wall; thence 48 degrees West one chain and sixty one links along edge of said wall to the center of the highway leading from the Lackawaxen Post office past the residence of said William C. Courtright thence along center of said Highway South 24-1/4 degrees East twenty-five links, thence North 54 degrees East one chain and sixty-eight links along lands of said Anna C. Gregory, to place of beginning.

CONTAINING 5/100 ACRES . . . The above courses are the magnetic bearings for the same for September 1921. This portion of land has been used since 1908 by the Bridge Company as an approach from the Highway to the Highland and Lackawaxen Bridge.[2]

The two Sullivan County parcels were conveyed to the Lackawaxen Bridge Company via two separate deeds. The boundaries of these parcels were:

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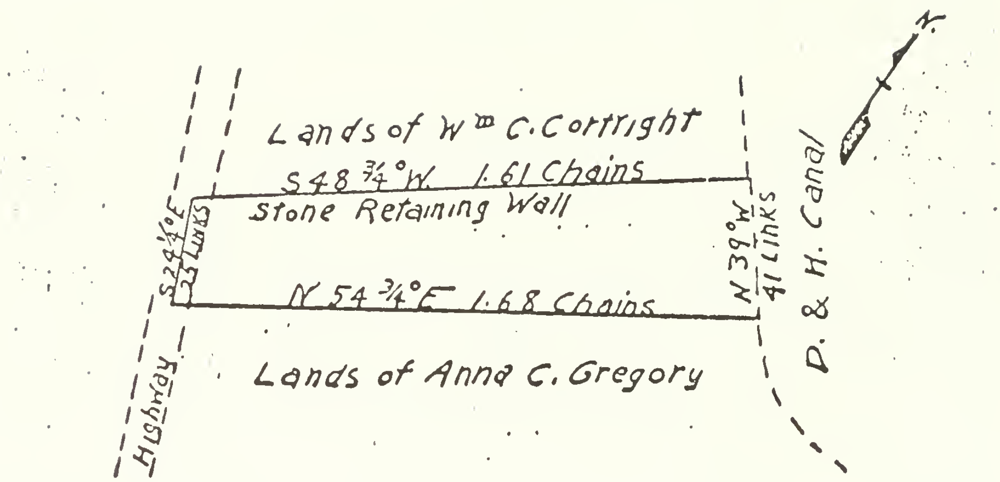
2. Deed, Charles Spruks and Nettie Spruks to Lackawaxen Bridge Company, dated November 1, 1930, Pike County Deed Book 84, Folios 386-88. A copy of the map accompanying the second parcel may be seen on the following page.


Lands of Wm C. Cortright
S 48 3/4° W. 1.61 Chains
Stone Retaining Wall
S 24 1/4° E 25 Links
N 54 3/4° E 1.68 Chains
N 39° W 41 Links
D. & H. Canal
Lands of Anna C. Gregory
Highway
N.

All that tract or parcel of land, situated in the Town of Highland, County of Sullivan and State of New York, consisting of a strip of land thirty (30) feet wide, bounded westerly by the easterly end of the Aqueduct formerly carrying the Delaware & Hudson Canal over the Delaware River and known as the Delaware & Hudson Canal Aqueduct; bounded easterly by a line, described in deed of Delaware Valley and Kingston Railway Company to Charles Spruks dated May 12th, 1908 as "the easterly line of lands of said party of the first part," which is a line drawn parallel with and distant fifteen (15) feet easterly from the Delaware & Hudson Canal, and bounded northerly and southerly by lines drawn parallel with and distant fifteen (15) feet (measured at right angles) northerly and southerly, respectively, from a line which would by an easterly extension of the center line of said aqueduct, together with so much of the Delaware & Hudson Canal Aqueduct aforesaid as now constructed and existing across the Delaware River from a point in said Town of Highland to a point in the Township of Lackawaxen, County of Pike and State of Pennsylvania, as is located in said Town of Highland and State of New York, together with the side roadways attached thereto and forming a part of said portion of said structure, and the wire cables, anchorages, supports, masonry, piers, and abutments supporting said portion of said structure, and all other appurtenances thereof, together with the land adjacent to the river occupied by said portion of said structure and its appurtenances, and any and all rights, franchises and easements to operate and maintain the said aqueduct and its appurtenances across and over said river. . . .[3]

All that piece or parcel of land situated, lying or being in the Town of Highland, County of Sullivan, State of New York, bounded and described as follows: Beginning at a point in the highway leading across the Delaware River to the hamlet of Lackawaxen, Pa. said point being S. 65° 19' E. 19.0 feet from transit point No. 1 of the March 1921 survey, which transit point is on the center line of the bridge, 39.5 feet from the north easterly corner of toll house, 32.05 feet from wall at the end of building just east of toll house, 33.5 feet opposite end of wall and 21.2 feet from the south westerly corner of building opposite end of bridge.

From the place of beginning S. 27° 27' E. 35.0 feet thence S. 62° 33' W. 65 feet, then S. 27° 27' E. 22 feet; thence S. 62° 33' W. 142 feet more or less to the edge of Delaware River thence along the edge of the Delaware River N. 27° 27' W. 145

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3. Deed, Charles Spruks and Nettie Spruks to Lackawaxen Bridge Company, dated November 1, 1930, Sullivan County Deed Book 276, Folios 580-83.

feet; thence N. 62° 33' E. 193.0 feet more or less; thence S. 73° 21' E. 84.19 feet; thence N. 62° 33' E. 51.77 feet; thence S. 67° 10' E. 20.44 feet; thence S. 27° 27' E. 15 feet and thence S. 62° 33' W. 110.17 feet to the place of beginning, containing 0.75 acres more or less.[4]

Little data could be found relative to Peter K. Schuyler or the Federal Bridge Company. One article written by Schuyler and published in the Engineering News--Record on December 4, 1930, does indicate his interest in toll bridges and in pending state and federal legislation affecting the construction and regulation of new bridges. He wrote that the number of highway toll bridges in operation in the United States had increased from 233 on October 1, 1927, to 296 on August 1, 1930. In addition 51 toll bridges were under construction throughout the nation. More than $1,000,000,000 was invested or contemplated for investment in toll bridges, including both public and private projects. Of the 296 bridges in operation, 96 or 31 percent were publicly owned, and the trend appeared to be toward increased public ownership of toll bridge operations. He observed that in some states toll bridges were classed as a public utility under the control of a public service commission. In Pennsylvania, where 17 toll bridges were located entirely within the state and eight were on the boundary lines, the intra-state bridges were subject to the jurisdiction of a public service commission which had the authority to regulate rates and service. The commission also had the authority to protect existing bridges against unwarranted competition by denying permission for construction of new structures if the existing ones were adequately serving the traffic needs of a given area. As both state and federal legislative bodies were considering legislation affecting the regulation and construction of new bridges, Schuyler urged that such prospective bills be given detailed study "so as to thoroughly protect the traveling public and assume the construction of only such bridges as are

4. Deed, Charles Spruks and Nettie Spruks to Lackawaxen Bridge Company, dated November 1, 1930, Sullivan County Deed Book 276, Folios 583-84.

warranted" and when constructed the bridges to operate "under adequate regulation."[5]

Almost as soon as the Delaware Aqueduct was purchased Schuyler published an article in Engineering and Contracting relative to his plans to rebuild the bridge to make it "suitable for highway traffic of the heaviest class." He noted that a "careful inspection of the structure showed the major portions of it to be in excellent condition" and that the stone masonry was "in excellent shape." His plans, which were "being made at present," included the "rebuilding" of "the floor system." This reconstruction work would involve the removal of the wooden canal trunk and the substitution of a simple floor system consisting of transverse floor beams hung from suspenders, longitudinal stringers, and plain transverse plank decking for the roadway.[6]

The reconstruction work was carried out and completed in 1930-31. The work was supervised by Thomas Andrews, an engineer employed by the Federal Bridge Company. Local help was recruited; among those who were thus employed were Herman Browser, Bernie Kunkell, Ben Campbell, Harvey Eldred, Charles Haas, Bill Shafer, and Carl A. Draxler. According to Arthur H. Haupt, the reconstruction work "had the advantage of revealing the suspension 'ropes' but the disadvantage of destroying the unique bridge-borne canal 'box.'" Southern pine or

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5. P. K. Schuyler, "Toll Bridges in Operation Total 296," Engineering News--Record, CV (December 4, 1930), 880.

6. Schuyler "Lackawaxen Suspension Bridge Rebuilt," 421, and Vogel, Roebling's Delaware & Hudson Canal Aqueducts, p. 26. The reconstruction effort was undoubtedly related to the increasing number of paved roads and the expansion of automobile traffic in Pike and Sullivan counties. For instance, the first paved roads were constructed in Pike County in 1927 and plans were underway for the realignment and pavement of Highway 97 in New York. Personal interview with Edwin D. LeRoy, March 1, 1983.

hemlock was presumably used for the new planking, deck, and stringers.[7]

Carl A. Draxler was one of the workers on the Federal Bridge Company's project to modernize the bridge. He remembers that the ends of the posts supporting the canal trunk were sawed off and the trunk sides were pulled down with ropes, section by section. According to his recollection the pier cap on the Pennsylvania span shifted as a result of the removal of the canal trunk rather than as a result of the May 30, 1933, fire as has generally been believed. Federal Bridge Company employees came to the Delaware Aqueduct for one week, but, saying the work was too dangerous, left the site. Thus local laborers, making fifty cents per hour, did virtually all of the work under the supervision of Thomas Andrews. On two occasions near-accidents occurred during the project: Shafer and Draxler almost fell into the river near the Pennsylvania shore when the hangers shifted suddenly; another time, after tools had dropped into the river, Draxler recovered them via a rope thrown over the bridge, but on his way back up the rope started unravelling. As part of the project the cables were wire brushed and painted with an anti-rust brown-colored substance. Loose wrapping was pulled off and painted, but no other changes to the cables or metal components of the bridge were made. Pier protectors or icebreakers, consisting of timbers bolted to the piers, were installed. Temporary walkways were built along the outside of the planking during the work. While some of the planking was being installed, the automobile caravan of Governor Franklin D. Roosevelt, on his way to dedicate the nearby Ten-Mile River Boy Scout Camp, was held up for nearly an hour.[8]

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7. "The Haupt's: Unofficial 'Historians' of the Roebling . . . The Haupt Photographs of the Dismantling of the Canal Bed . . ," Upper Delaware Magazine, I (Winter/Spring, 1979), 11, 33. Haupt, an ardent amateur photographer, took some photographs of the dismantling of the canal trunk, copies of which may be seen at the back of this report.

8. Personal interview with Carl A. Draxler, May 3, 1983.

About the time of the bridge modernization project John H. Redding lived in the toll house and served as the bridge overseer for the Federal Bridge Company. After the project was completed a Mrs. Heflin served as the daytime toll keeper and Draxler worked from 6 p.m. to 11 p.m. during the summer months, both earning fifty cents per hour. The Federal Bridge Company provided forms for the toll collectors to fill out for the purpose of record keeping. Draxler remembers the local people cussing the "toll bridge," with many of them driving to Shohola to cross the river "free of charge" or waiting until the toll collector went home at night.[9]

A major fire broke out at the Delaware Aqueduct during the night of May 30, 1933, destroying the woodwork of the westernmost span on the Pennsylvania side of the structure as well as a significant portion of the span adjacent to it.[10] While the story of the fire has not been fully authenticated or documented, Austin Smith of Barryville and Arthur H. Haupt of Lackawaxen have indicated that the general feeling of area residents was that the fire was started with gas and matches by local persons wanting a modern toll-free bridge with no weight limit.[11] Although fire companies with pumpers had been formed on both sides of the Delaware during the late 1920s, the fire was fought, at least in part, with water drawn from the river in buckets by ropes.[12] While the fire was widely referred to as a case of arscn, no law enforcement agencies pursued the matter. According to Arthur H. Haupt, who served as the justice of the peace in Lackawaxen for some thirty-five years, it was generally agreed that the bridge was "under the sole authority of the

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9. Ibid., and personal interview with Arthur H. and Annabel Haupt, May 4, 1983.

10. There are several timbers on the bridge today showing the charred effects of fire damage.

11. Personal interviews with Austin Smith, May 3, 1983, and Arthur H. and Annabel Haupt, May 4, 1983. It is possible that the fire might have resulted from rising feelings against the purchase and reconstruction of the bridge by a New York City-based firm.

12. Personal interview with John Traber, Barryville, New York, May 5, 1983, and letter, Olive Brower Finenko to Harlan D. Unrau, May 12, 1983,

owner." Thus, law enforcement agencies never became involved in any incidents related to the structure.[13]

Repairs to the charred bridge were commenced within two weeks. On June 15, 1933, The Hancock Herald reported that:

> The cables and hangers sustaining the historic four-span "D & H" canal viaduct at Lackawaxen, Pa., on the main line of the Erie were not seriously injured by the fire on May 30th that destroyed the woodwork of the two spans of the structure. A contractor is hauling timber for repairs, and it is expected that within a short time the charred woodwork will be replaced and that the bridge, built originally as a viaduct for canal boats operating from Honesdale to Rondout, will be reopened for highway traffic. Ever since the canal was abandoned in the early [late] nineties, the structure had been used as a roadway, and it was almost indispensable for people of the neighborhood, the nearest other bridges being at Narrowsburg to the north and Pond Eddy to the south.[14]

Following repairs to the woodwork of the bridge the roadway was tarred and gravel chips spread on the new plank decking. This work was carried out by a crew from the Pennsylvania Highway Department, a division of the State Department of Public Works.[15]

The Delaware Aqueduct was discussed in F. H. Frankland's Suspension Bridges of Short Span in 1934. He observed that the "only multiple-span highway suspension bridges yet built in the United States are the old Roebling bridge in Pittsburgh" and "the Lackawaxen Bridge over the Delaware River." Regarding the latter he noted that "the sag of the cables is about 1/12 and consequently the structure is remarkably rigid, although some of this rigidity is due to the fact that, for highway loading, the cables are considerably oversize."[16]

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13. Personal interview with Arthur H. and Annabel Haupt, May 4, 1983.

14. The Hancock Herald, June 15, 1933.

15. Personal interview with Austin Smith, May 3, 1983. Smith was a member of the crew that did this work.

16. F. H. Frankland, Suspension Bridges of Short Span (New York, 1934), p. 85.

Soon after the fire damage was repaired and the bridge reopened the William John (Jack) Brower family moved into the toll house. Mr. Brower managed the toll collection operations and supervised the maintenance activities at the bridge on behalf of the Federal Bridge Company until his death in 1940.

Considerable information about the Browers during the 1930s was provided to the author of this report by Mrs. Olive Finenko of Chenango Falls, New York, in a letter dated May 12, 1983. The Brower family, consisting of three children (Kathryn aged 15, Jack Jr., aged 8, and Olive, aged 13), arrived at the bridge in June 1933 with a small truck packed with furniture. They moved from Oil City, Pennsylvania, where Mr. Brower had been working at the Reno Toll Bridge for the Federal Bridge Company.

The toll house at the Delaware bridge, consisting of "five small rooms, no bath, no water, only electricity," was small and primitive compared to their quarters at Oil City. The "privy" was on top of the abutment across from the toll house. The two rooms downstairs in the toll house were the kitchen and living room with three bedrooms upstairs. The river was the source of wash water, a pulley being fastened on the cable just beyond the first pier on the upriver side to pull water up by bucket. Their drinking water was obtained from a spring across Highway 97 from the toll house. A shed was attached to the west end of the toll house and at the end of that was a gas pump where the Browers pumped gas--the price varying between 7 to 10 gallons for $1.

While the Browers were at the bridge all repairs were done by Jack Sr. and Jack Jr. When the planks would loosen, one of the Browers would take a hammer and drive in the spikes.

The entire family helped collect tolls and open the gate to allow vehicles to pass. Local residents would help to relieve the Browers if they went away. Harvey Eldred helped to repair the roof of the toll house one year, and the entire Brower family helped to paint the toll house on one occasion.

A daily sheet was filled out for the Federal Bridge Company, denoting the number of vehicles, pedestrians, and gallons of gas pumped for each hour of operation. The sheets along with a postal money order were sent to Peter Schuyler in New York on Mondays and Fridays. Tolls for cars were twenty-five cents and for pedestrians two cents. An average of $20 (including gas) was sent to Schuyler twice a week. A sliding slot in the window toward the bridge (near where the tally sheets were kept) permitted toll collection from pedestrians.

Bill Shafer, one of the Lackawaxen men who had worked on the bridge in 1931 and after the fire, crossed the bridge frequently by "walking" the cables and thus avoiding the tolls. Ben Campbell, another man who had worked on the bridge, walked from his home in New York to Lackawaxen every day. Since he received his pension check once a month he paid his tolls at the first of every month "along with candy for the kids."

When the ice on the river broke up in spring the bridge was a favorite spot for spectators with up to 30-40 people watching at a given time. When someone would holler "here comes the big one," people would run to the pier that the ice was moving toward to see if it broke up or "climbed the pier." When the dam on the Lackawaxen broke at Hawley, the Browers watched parts of houses, barns, chicken coops, and trees pass under the bridge.

In winter the wind and the sway of the bridge helped to clear the bridge of snow. The roadway between the edge of the bridge and Highway 97 was shoveled by the Brower children.

The Brower family experienced tragedy in 1940 as Kathryn died in May and Jack Sr. died in December. Olive was already married, and her mother and Jack Jr. moved from the bridge during the summer of 1941.[17]

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17. Olive Brower Finenko to Harlan D. Unrau, May 12, 1983. Mrs. Finenko is the last living member of her family.

One of the more bizarre incidents to occur at the bridge took place in 1940. A man from Eldred, New York, flew an airplane under the bridge's center span as a stunt.[18]

18. Personal interview with Arthur H. and Annabel Haupt, May 4, 1983.

CHAPTER TWELVE

THE DELAWARE AQUEDUCT UNDER THE LACKAWAXEN BRIDGE COMPANY (EDWARD H. HUBER, OWNER): 1942-73

On June 1, 1942, Edward H. Huber, a lumber broker from Scranton and a nephew of Charles Spruks, purchased the Lackawaxen Bridge Company, and hence the Delaware Aqueduct, from the Federal Bridge Company. The conveyance consisted of the transfer of the entire 100 share of stock in the Lackawaxen Bridge Company to Huber as well as the assignment of the $35,000 mortgage originally pledged by the Lackawaxen Bridge Company to Charles Spruks in November 1930. Since the transfer of property was conveyed by an exchange of stock no deed was recorded in the county land records.[1]

Edward H. Huber, son of Edward Huber and Anna Spruks Huber, was born in Atco, Pennsylvania,. There he received his early education in the local rural schools and later pursued higher education in the Wharton School of the University of Pennsylvania. He moved to Scranton in 1916 and was first employed by the Bulls Head Coal Company, owned by Jonathan Vipond, S. S. Spruks, David Spruks, Jay Law, and John Stansbury. After several years he went to work for the Spencer Coal Company of Dunmore. After serving in the Navy during World War I, he and his brother Stephen S. Huber organized the Bell Grocery chain of food stores which quickly grew to operate 55 stores between Honesdale and West Pittston. In 1928 he disposed of his interest in the chain and began working for the Pacific Oil Company. After two years he became area representative of the Tidewater Oil Company. In 1938 he organized the Hawk Oil Company, distributing petroleum products in the Scranton area. Early in 1940 he sold his interest in that company to manage the business of his uncle, Charles Spruks, one of Scranton's largest brokers

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1. Assignment of Bond and Mortgage to Edward H. Huber, June 1, 1942, Sullivan County Mortgage Book 322, Folio 361, and "Lackawaxen Bridge Company Stock Certificate, June 1, 1942," Edward H. Huber Collection, Scranton, Pennsylvania.

in mining supplies, and on his uncle's death, he took over the business. In this capacity he sold heavy timber to mines throughout northeastern Pennsylvania, sometimes requiring 60 to 70 truck loads of lumber per day from his holdings in the Virginia-Maryland region to service his customers. In addition to his purchase of the Lackawaxen Bridge Company he also owned several mines and was an officer of others.

In December 1968 Huber was elected vice president of the South Side Bank and Trust Company of Scranton, a position he still holds with the present-named Penn Security Bank and Trust Company. A member of the Dunmore Methodist Church, he served for many years as trustee and treasurer of the Methodist Homes for the Aging, Wyoming Conference, and played a prominent role in the establishment of the home for the aged in Atco, Pennsylvania.[2]

Huber purchased the Delaware Aqueduct for speculative purposes, hoping to sell the structure to the states of Pennsylvania and New York at a profit. Political involvements prevented such a sale as officials of both states could not agree on a "deal" for the transfer.

During his ownership of the structure the toll operation was generally open in winter until 6:00 p.m. in the evening, and in summer it was frequently open until midnight. If the weather were bad and there was little business, Huber instructed his toll collectors to go home after which passage was free. In 1942 the toll was 25 cents for vehicles and 5 cents for pedestrians, with passage on Christmas Day free. By 1970 the toll rates were 25 cents for cars, 15 cents for motorcycles, 35 cents for pickups, and 5 cents for pedestrians. The speed limit was 5 miles per hour, but local residents remember many instances when vehicles would travel from 20 to 30 miles per hour over the span. The bridge was insured for a six-ton load limit, but this limit was not strictly enforced,

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2. Unidentified newspaper clipping, ca. 1968, Edward H. Huber Collection, and personal interview with Edward H. Huber, Scranton, Pennsylvania, March 25, 1983.

in part because it was known that the bridge would hold considerably more weight. Thus, mail trucks, feed trucks, and heavy tractor-trailer trucks carrying loads of up to 20 tons of brick and 60 tons of lumber were known to use the bridge regularly. Moreover, the limit could not be strictly enforced, in part because there was no regulation of bridge traffic once the toll collector went home at night. During the 1950s there was one reported instance when the driver of a truck and trailer hauling a load of 32 tons of steel waited until 2:00 a.m. to cross the span.

During his years of ownership Huber maintained the bridge with the help of local railroad employees who worked some evenings and weekends. Huber himself spent many weekends at the bridge, bringing work crews from Scranton, supervising the maintenance activities, and "swinging a sledgehammer himself" until the age of 75.

Clarence Miller of Minisink Ford served as Huber's bridge and maintenance superintendent, and after 1958 Miller's son-in-law, Orson Davis of Minisink Ford, took over as Huber's primary maintenance supervisor.

At first Huber used local oak and hemlock timbers for the periodic replacement of stringers and planking. In later years these types of timber were not readily available so he used oak timber from Virginia, Maryland, and Georgia that he acquired as part of his lumber operations. The timber pieces were creosoted in Baltimore before being trucked to the Delaware Valley. As a normal routine the stringers and planking on one or two spans would be replaced each year either in spring or fall, using one tractor-trailer load of lumber per year. The old planks were raised with the aid of a broom attached to the front of a car or pickup. A continuous problem was the tendency of the timber pieces to rot as a result of the constant exposure to the damp climatic conditions in the Delaware Valley--a problem that made repairs both frequent and expensive. According to Huber, the bridge was a "non-profit operation" because the cost of maintenance was usually higher than the revenue realized from the tolls.

Every five years or so the cables and metal components of the bridge were scraped with wire brushes and then painted with black rust-resistant type paint. Oil was put under the saddles to increase their mobility. New wrapping was installed as needed, and steel bands were sometimes placed around the portions of the wrapping where it was broken and the cables exposed before painting. On at least one occasion a drunken driver hit the suspender rods and bent them, necessitating their removal and straightening.

Several times during his ownership of the bridge the upstream side of the pier abutments was covered with a cement facing. On at least one occasion a cofferdam was erected around the piers to permit the repointing and rehabilitation of the stonework in the pier foundations. Much of this work was carried out by men using a boat.

Other than the problems involved with the maintenance of the bridge the two chief difficulties faced by Huber were that of vandalism and inaccurate accounting procedures by some of his hired toll keepers. Vandalism, presumably carried out by local residents, was a continuing frustration of Huber throughout his ownership of the bridge. At various times he was afraid that some of his hired toll keepers were cheating him out of toll receipts. For example, he found that some delivery trucks were allowed to pass without paying tolls if they provided the toll keepers with a "gift" of their merchandise. Sometimes Huber would drive from Scranton to spend summer evenings out of sight on the Lackawaxen side of the bridge tallying the number of vehicles passing over the span to see if the toll keepers were giving him an accurate accounting of the traffic. In later years Huber paid some of the toll keepers a percentage of the money they received in tolls as pay.

During the early years of his ownership of the bridge some of his hired toll keepers lived upstairs in the toll house. In later years the upstairs was converted into two storerooms and the downstairs remodeled into an office and supply and tool room after the oil shed was removed. Although he made no major structural changes to the toll house during his ownership, Huber painted it periodically, changing the color from

gray or beige with green trim to red. Huber had it heated with a coal stove, and made necessary repairs, especially when a vehicle would brush against it. Screens were installed over the windows to save them from vandals. A new roof was put on the structure by Joseph Smith, a local resident, several years before he sold the structure in January 1973. The cement block just outside the toll house was put in during the 1950s at which time a sturdy, wooden gate was installed replacing the lattice-work gate.

A number of improvements were made to the bridge and toll house during the Huber years. Although electric lines had been run across the bridge during the 1920s, lights were not installed on the structure until the 1940s. A telephone was installed in the toll house during the late 1940s or early 1950s. New electric lines were run across the bridge by Arthur H. Haupt in the late 1940s or early 1950s (about the time television was introduced at Lackawaxen).[3]

The reminiscences of Leona Davis, a life-long resident of Minisink Ford, provide further details of the operation of the bridge during the 1950s and 1960s. She served as a part-time toll collector during weekends in 1954-55. Her father Clarence Miller served as toll collector and bridge superintendent for many years, and her husband Orson Davis became the primary maintenance supervisor of the bridge in 1958.

During the 1950s and 1960s there was sometimes heavy traffic on the bridge, particularly on weekends, that was related to the railroad yard and feed mills at Lackawaxen as well as the Jewish summer camps on both sides of the river. Although cars were allowed to pass on the bridge

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3. Personal interviews with Edward H. Huber, March 25, 1983; Arthur H. and Annabel Haupt, May 4, 1983; Orson Davis, Minisink Ford, New York, May 5, 1983; Leona Davis, Minisink Ford, New York, May 5, 1983; George Shork, Narrowsburg, New York, May 3, 1983; and Carl A. Draxler, May 3, 1983. Also see New York Times, June 11, 1967; The Scranton Tribune, July 23, 1970; The Scrantonian, November 8, 1970; New York News, September 26, 1971; and The Pocono Record, February 6, 1983.

drivers tended not to pass each other out of courtesy and custom. Strings of cars often would cross the bridge before vehicles from the opposite direction would venture on to the span.

The toll collector pumped gas from the pumps located between the toll house and Highway 97. A daily tally sheet was kept by the toll collector on a desk in front of the window on the bridge side of the toll house, detailing the weather, gas tank readings, pedestrians, and number and types of vehicles that passed over the bridge each hour. The toll collector was supposed to "walk" the bridge every day, noting problems that required attention. When Huber was notified that repairs were required, he would have the bridge superintendent order the necessary materials and commence the work as quickly as possible.

Mrs. Davis remembers a number of interesting and colorful experiences at the bridge. During a spring rain a lady going too fast on the bridge got her car turned crosswise across the bridge and required help to get the car off the span. Every Memorial Day a ceremony was held at the cemetery in Lackawaxen. During the playing of "taps" at the cemetery a man with a wreath marched to the center of the bridge, which was closed for the occasion, and threw the wreath into the river. At one point a man brought a box of ashes (the remains of a relative) and poured it over the edge while Huber was on the bridge. During the early 1960s Billy Graham crossed the bridge on his way to a meeting in Scranton.

During the 1950s and 1960s local area people resented the payment of tolls at the bridge. This feeling was partially assuaged by the sale of ticket books (for eight trips) at the toll house which entitled the purchaser to two free trips for both cars and pedestrians. If a person bought gas he did not have to pay the toll. Companies whose trucks regularly passed over the bridge had monthly accounts.

Vandalism was a continuous problem at the bridge. While the bridge generally closed in the evening, weather conditions and the number of young people in the vicinity of the bridge often determined when the toll collector could go home. Sometimes the collector stayed at the toll house

until the early morning hours. While there were no robberies during the Huber period, there were occasional incidents in which a plank or part of the guard rail would be ripped out and thrown into the river. The lights on the bridge were often broken with rocks or bullets.

Weather conditions sometimes caused problems at the bridge. During Hurricane Diane in August 1955 flood waters on the Delaware splashed the planks of the bridge but caused no appreciable damage to the structure. During the winters the abutments would freeze, sometimes raising the height of a span. The bridge and approaches were sanded by the toll collectors and local men, primarily Orson Davis, and trucks and snow plows would clear the bridge of snow.[4]

In the late 1960s an article appeared in the New York Times indicating that the bridge "is and has been 'for sale.'" After owning the bridge for some 27 years Huber was quoted as saying that "the bridge business, even when good, can get a bit monotonous in that length of time." The bridge remained "tremendously strong" although there was a posted "six-ton limit" sign at the structure. Recently, a truck with 28 tons of stone had crossed the structure but such a load was considered dangerous. Under some "overloads" stringers had been broken in the bridge. The stringers under the planks were 5 inches by 14 inches and 24 feet long--a size lumber seldom seen anymore. The principal work of upkeep concerned

> occasional replacing of the two and a half inch thick oak planks which form the bridge floor. The width of the bridge requires two such planks, butted end to end. They are nailed down with five 60-penny spikes.
>
> During the summer months there is a toll-taker on duty 24 hours a day. In the months when there is much less activity, the late night and early morning hours are "free."
>
> Most regional people, glad to be able to avoid a drive of many miles in either direction in order to cross the Delaware, buy books of tickets. Those who use the bridge only occasionally pay the regular tolls. . . .

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4. Personal interview with Leona Davis, May 5, 1983.

Huber noted that the "closest call" for the bridge had occurred during a flood when two partly-filled 20,000-gallon gas tanks broke loose at Honesdale and floated down the Lackawaxen. As a result of being partly-filled, the tanks

> floated along at an angle, with part of the tank sticking out of the water. As the one tank approached the bridge it was tilted with the top downstream--a condition that would have made it a dangerous battering ram when it hit the bridge. Fortunately, as it approached, it swung around and, with the top tilted upsteam, merely hit the bridge a glancing blow and continued on downstream.[5]

Huber continued to advertise his intention to sell the bridge. In October 1971 Grit quoted him as saying he would "dearly love to sell that bridge" because it required more time than he had to spare. Help was difficult to secure and he did much of the work himself. The hardest job was "driving those 60-penny spikes" which held the floor to the subfloor--a recurring problem since vibration loosened them.[6]

In 1971 Robert M. Vogel, Curator of the Division of Mechanical and Civil Engineering in the Smithsonian Institution's National Museum of History and Technology, described the condition of the bridge in his Roebling's Delaware & Hudson Canal Aqueducts. According to Vogel the fabric of the structure was

> in generally good condition. The masonry, except for an understandable minor deterioration of the upstream pier faces from river ice, is quite perfect. The floor system is good as the planking is periodically replaced, and the cables, despite unwinding of the outer wrapping in a few areas, are kept painted and appear as adequate as when spun. The posted allowable load of six tons is almost ludicrous in view of the fact that each span originally contained about 500 tons of water plus the additional dead load of the trunk and towpaths. True, it was an evenly distributed, non-moving, non-impact load, but

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5. Undated article from New York Times (ca. 1969) in William H. Stephens, comp., "D & H Canal," scrapbook, Wayne County Historical Society, Honesdale, Pennsylvania.

6. Grit, October 3, 1971.

there can be little doubt that the cable system today is not working very hard.[7]

In November 1972 Huber formally placed the Delaware Aqueduct on the market and announced that his tentative sale price was $100,000. Two months earlier he had indicated that the bridge had been "a non-profit operation from the standpoint that the cost of maintenance" had "been higher than the revenue realized." The fact that it was designated a National Historic Landmark in 1968 had "created additional expense" since its landmark status was bestowed "under the premise that it would be maintained in the same manner as it was originally built."[8]

In the wake of his announcement several potential buyers made offers. At the same time various professional, historical, and political interest groups became alarmed at what might happen to the bridge if it were sold. Joseph M. Purcell, administrator of the Sullivan County Parks and Recreation Commission, was afraid the bridge might be destroyed and thus attempted to help Huber sell the structure to local government agencies who would preserve and interpret the structure as part of a historical park. At the same time he pressed for state-federal-county funding to enable the aqueduct to become a county or municipal park with historic emphasis and picnic facilities.[9] William M. Rice, an AIA architect in New York wrote to Huber saying that it was "inconceivable that the various appropriate historical and engineering societies have not shown sufficient gumption to assure safe ownership." Charles Birnstiel, a professor in the School of Engineering and Science of New York University, informed Huber:

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7. Vogel, Roebling's Delaware & Hudson Canal Aqueducts, p. 26.

8. Stango to DePasquale, September 7, 1972, DePasquale to Stango, October 6, 1972, and unidentified newspaper clipping, Danny A. Stango Collection, Dunmore, Pennsylvania.

9. The (Middletown, New York) Times-Herald Record, March 11, 1967, May 3, 1968.

It is difficult to overstate the significance of this structure in the historical development of the art of suspension bridge construction. I hope that the buyer will appreciate this and preserve the structure in its present form, except for repairs to the cable wrapping, deck and guard rails, and operate it as a service to the local communities. It would be a shame if Roebling's original fabric were altered. Even worse, would be an attempt to relocate the structure.

If events should make it necessary for you to consider selling the bridge to a party for scrap, or one that intends to alter it substantially, or a party that intends to move it, I would appreciate an opportunity to discuss the matter with you.[10]

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10. Telephone interview with Joseph Purcell, April 7, 1983; and Rice to Huber, December 1, 1972, and Birnstiel to Huber, December 5, 1972, Stango Collection.

CHAPTER THIRTEEN

THE DELAWARE AQUEDUCT RECEIVES ATTENTION AS A NATIONALLY-SIGNIFICANT HISTORIC AND ENGINEERING LANDMARK: 1970-72

The Delaware Aqueduct was a largely-forgotten historic and engineering treasure for more than 100 years. At its 100th anniversary in 1949 one local writer observed about the structure:

> . . . A victim of time and change, it still serves an economic purpose and has survived where most contemporaries have long since been replaced. To the knowing, its solid stone masonry and stout pine timbers remain in mute testimony to the permanency of its construction and reflect additional credit upon the persistent applications of thorough and practical acumen that were so characteristic of its builders.
>
> Now, bowed by the burdens of years and gray with the dust of neglect, it yet stands; a grim, defiant veteran of the past, symbolic of the glories it once knew, of the destinies it helped to shape, and withal, an enduring tribute to our Country's pioneer spirit, from which it was conceived.[1]

Interest on the part of various local government organizations and historical societies for designation of the Delaware Aqueduct as a National Historic Landmark emerged during the spring of 1967. On March 13, 1967, Manville B. Wakefield, author of <u>Coal Boats to Tidewater</u>, introduced a resolution that was passed by the Sullivan County Historical Society urging establishment of the "Roebling Suspension Bridge" as a National Historic Landmark.[2]

As part of the effort to obtain National Historic Landmark status for the Delaware Aqueduct an engineering study of the structure was

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1. Fred Suydam, "Old Bridge Observes Centennial: Delaware Aqueduct Celebrates 100th Anniversary," July 7, 1949 (typescript copy, Pike County Historical Society).

2. Resolution, Sullivan County Historical Society, March 13, 1967, Wakefield Collection, Delaware and Hudson Canal Historical Society.

undertaken by Mayo and Lynch of Hoboken, New Jersey, at the request of the New York Council of the Arts. The study was designed to develop proposals to stop deterioration of the cable suspension system and estimate the extent of necessary repairs. Among other items the engineers noted that the cable's wrapping was unwound in many places, thus exposing the wire strands. Rust and exposure had eaten away at the metal components of the structure, and two stone piers had moved at the middle where strain on the load-bearing members was greatest.[3]

Sullivan County park administrator Joseph M. Purcell supported the effort to obtain landmark status for the aqueduct and was one of those who initiated inquiries with the Northeast Regional Office of the National Park Service in Philadelphia in August 1967. In February 1968 the Sullivan County Historical Society made similar inquiries about the aqueduct's potential for landmark status. By June 1968 the offices of U. S. Senators Robert F. Kennedy and Jacob K. Javits of New York and Joseph S. Clark of Pennsylvania and U. S. Congressman Joseph M. McDade of Pennsylvania had contacted the National Park Service on behalf of further inquiries by the Sullivan County Historical Society. As stated by James M. Staples on May 14, 1968, it was the position of the society that:

> Although in some respects showing the wear of more than a century of exposure to the harsh weather of the region, the bridge today remains a sturdy tribute to the engineering genius who was later to build the Brooklyn Bridge and many other notable spans.
>
> Aside from its obvious historical merit, the bridge contributes greatly to the nostalgia of a region which in essence is still remote in time from the fast approaching tensions of urbanization. Aesthetically, it and its quaint red, posted bedecked tollhouse lend artistic charm to the placid valley of the Delaware and at the same time evoke memories of a younger America, when visionary men wove a network of canals to open a country's heartland to commerce and settlement.

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3. The (Middletown, New York) Times-Herald Record, March 11, 1967.

Today the scenic and historic upper Delaware River valley remain singularly isolated from the mainstream of American tourism, and accompanying commercialization. This condition now, however, is about to change radically under the impetus of such developments as the Federal Interstate Highway system and the Delaware Water Gap National Recreation Area. National Historical Landmark status for the old Roebling Bridge would serve both to identify its significance to the casual tourist, and to safeguard it against some future development which might diminish its charm and validity.[4]

As a result of these efforts NPS historian John D. McDermott completed a special report on the Delaware and Hudson Canal for the National Survey of Historic Sites and Buildings. In the report the aqueduct was declared to be one of five well-preserved sections of the nationally-significant canal.[5] Based on the report Secretary of the Interior Stewart Udall declared the canal to be eligible for registered National Historic Landmark status that same year. The following year the Delaware Aqueduct was identified as the "oldest suspension bridge in the United States that retains its original elements and the earliest extant example of Roebling's engineering genius" in the Mohawk-Hudson area study conducted by the Historic American Engineering Record.[6]

On July 22, 1970, a ceremony with some 150 people in attendance was held at the site of the aqueduct commemorating the designation of the structure as part of the registered Delaware and Hudson Canal National Historic Landmark.[7] The program was organized and led by Danny Stango, a

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4. Staples to Nelligan, May 14, 1968, Staples to Javits, May 17, 1968, and Jensen to Javits, June 25, 1968, Stango Collection; and telephone interview with Joseph M. Purcell, April 7, 1983.

5. McDermott, "Special Report, Delaware and Hudson Canal."

6. Robert M. Vogel, ed., A Report of the Mohawk-Hudson Area Study: A Selective Recording Survey of the Industrial Archeology of the Mohawk and Hudson River Valleys in the Vicinity of Troy, New York, June-September 1969 (Washington, 1973), p. 151.

7. The Scranton Tribune, July 23, 1970; Pike County Dispatch, July 30, 1970; The Scrantonian (Pictorial Section), August 30, 1970; The Wayne Independent, July 16, 18, 21, 23, 1970; and (Port Jervis) Union Gazette, July 23, 30, 1970.

relative of Edward H. Huber and a New York Life Insurance agent in Scranton, Pennsylvania, and Manville B. Wakefield. Those offering remarks during the program included: C. Albert Sharkey, supervisor, Town of Highland; Joseph M. Purcell, administrator, Sullivan County Parks and Recreation Department; Paul M. Sturges, chairman, Delaware and Hudson Canal Historical Society; and Robert M. Vogel, curator, Smithsonian Institution. The principal speech for the occasion was given by John Bond, Chief, Interpretation and Resource Management, New York City Group, National Park Service, followed by the formal presentation of a certificate to Huber. The bronze plaques denoting National Historic Landmark status had already been mounted on the New York and Pennsylvania abutment walls of the structure.[8]

In early November 1970 a camera crew from WCBS, the Columbia Broadcasting System affiliate in New York, filmed a five-minute documentary on the Delaware Aqueduct. Additional film footage was taken several weeks later. The film clips were made available to a number of Delaware Valley CBS-affiliates for local showing as well as to various cable television services. According to Craig Spence, WCBS director of

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8. Memorandum, Director, Northeast Region, to Director, Washington Office, July 20, 1970; "Lackawaxen Bridge, Delaware and Hudson Canal Registered National Historic Landmark - Ceremony Held on July 22, 1970 - John Bond, Chief, I & RM Remarks"; Registry of National Historic & Natural Landmarks, Preservation Ceremony Report, August 31, 1970; and "Program Commemorating the Presentation of National Historic Landmark Plaque for the Lackawaxen Bridge, July 22, 1970; Land Resources Division Files, Mid-Atlantic Regional Office, National Park Service. There is considerable material relating to this ceremony in the files of the Danny Stango Collection. Photographs and a cassette tape recording of the ceremony have been duplicated from this collection and are on file in the park files of Upper Delaware National Scenic and Recreational River. The aforementioned program brochure listed the formal corporate organization of the Lackawaxen Bridge Company: E. H. Huber, president; Elizabeth Huber, treasurer; Elmer Acker, vice president; Clarence L. Miller, bridge superintendent; and Lee Miller Davis, assistant bridge superintendent.

the documentary, the film afforded a "nostalgic look at a slice of Americana" that was still being used.[9]

The significance of the Delaware Aqueduct as a National Historic Civil Engineering Landmark was recognized by the American Society of Civil Engineers during its annual meeting in Houston, Texas, on October 18, 1972. Accordingly, the Lehigh Valley Chapter of that organization placed two bronze plaques on the bridge (one on each side of the river) during a ceremony held at the site on November 12. Robert E. Nolan, Jr., incoming president of the chapter and a member of the architectural and consulting engineering firm of Bellante, Clauss, Miller and Nolan in Scranton, was in charge of the arrangements committee and served as master of ceremonies. Oscar Bray of Boston, the immediate past president of the National Society of the ASCE, dedicated the plaques.[10]

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9. The Scrantonian, November 8, 1970. Efforts should be made by the National Park Service to acquire this film clip for use in its interpretive program for the bridge.

10. Nolan to Stango, October 27, 1972, and News Release, Sullivan County Publicity and Tourism Department, October 26, 1972, Stango Collection, and Press Release, American Society of Civil Engineers, "Roebling's Delaware Aqueduct is Designated A National Historic Civil Engineering Landmark," November 2, 1983, in William H. Stephens, comp., "D & H Canal."

CHAPTER FOURTEEN

THE DELAWARE AQUEDUCT UNDER THE LACKAWAXEN BRIDGE COMPANY (ALBERT L. KRAFT, OWNER): 1973-80

On January 15, 1973, Albert L. Kraft, a telephone company employee and a resident of Hawley, Pennsylvania, purchased the Lackawaxen Bridge Company, and hence the Delaware Aqueduct, from Edward H. Huber. The sale of the bridge consisted of the transfer of the entire 100 shares of company stock as well as assignment of the $35,000 mortgage that Huber had assumed in 1942. A special meeting of the stockholders, with Huber as chairman, was held at the home of Huber in Scranton on January 15 at which time three new directors were elected: Albert L. Kraft, his wife, Jean R. Kraft, and David A. Kraft, the Krafts' oldest son. A second meeting was held that day at the Krafts' home in Hawley at which time the following officers were elected: Albert L. Kraft, president, David A. Kraft, vice president, and Jean R. Kraft, secretary and treasurer.[1]

Because the transfer was a stock transfer transaction, no deed of conveyance was recorded in the county land records. According to Huber, the terms of agreement included a down payment by Kraft with installments to follow and with Huber holding a lien against the bridge company.[2]

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1. "Assignment of Bond and Mortgage Given E. H. Huber to Albert L. Kraft and Jean R. Kraft, his wife," January 15, 1973; Lackawaxen Bridge Company, Minutes of Special Meeting of Stockholders, January 15, 1973; Lackawaxen Bridge Company, Board of Directors, January 15, 1973; Waiver of Notice of the Special Meeting of Stockholders, Lackawaxen Bridge Company, January 5, 1973; Assignment Separate from Certificate, January 15, 1973; Huber Collection.

2. "Appraisal Report of Tract No. 101-01, Lackawaxen Bridge, Town of Highland, Sullivan County, New York, Lackawaxen Township, Pike County, Pennsylvania, Upper Delaware Scenic and Recreational River Project . . . Prepared for National Park Service, Mid-Atlantic Regional Office . . . by W. L. Moore & Son . . . Easton, Pennsylvania . . . April 16, 1979," p. 8, and personal interview with Edward H. Huber, March 25, 1983.

When Gene Peluso, Landmark Specialist with the National Park Service's Mid-Atlantic Regional Office, visited the Delaware Aqueduct in April 16, 1973, he noted that the "bridge is very sturdy and in no danger of being a safety hazard." He observed, however, that "wooden portions of the siding could use a painting." The immediate area of the bridge was "littered with pieces of wood which were taken from the bridge as being non-serviceable." The grounds required "leveling out and maintenance." The canal bed near the New York abutment was "filled with everything that people can throw in it plus weeds galore." Restoration of the toll house was already underway with the second floor intended for conversion to use as a gift shop. An outside stairway leading to the second floor was also planned. When this was completed Kraft intended to clean the canal bed and level out the nearby terrain for use as a parking lot.[3]

In July 1973 the Society for Industrial Archeology Newsletter reported on the acquisition of the Delaware Aqueduct by Kraft. The article noted that the new owner was "fully appreciative of the venerable span's extraordinary historical importance." Kraft already had "replaced much of the timberwork of the deck." During the coming fall he intended to "remove rust and repaint the main cables, suspenders and other ironwork." His long-range plans were "to rework the approaches, repoint the pier and abutment masonry, and construct some type of ice protectors for the upriver masonry faces." He had also taken steps to draw public attention to the structure, provide visitor facilities, and open a gift shop.[4]

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3. Registry of National Historic Landmarks, Report of Biennial Visit to "D & H Canal, Penn. New York Lackawaxen," April 16, 1973, Land Resources Division Files, Mid-Atlantic Regional Office. At this time Kraft stopped selling gas and removed the pumps. Personal interview with Leona Davis, May 5, 1983.

4. "Delaware Aqueduct Sold - But It's OK!," Society for Industrial Archeology Newsletter, II (July, 1973), 1.

A brochure prepared by Kraft advertised the items for sale in the Toll House Gift Shop when it opened on the second floor of the structure. The items included: post cards, stationery, candles, film, candy, baskets, fenton glass, Americana pine articles, jewelry, pepsal mills, and books on local history. Mugs and tiles by Tink Wig Pottery of Hawley, Pennsylvania, were also for sale. Among the items from the Hawley shop were special tile with bridge replica, handcrafted dolls, hand-carved onyx items, lamps, wind chimes, and toys. Purchase of $1.00 or more in the gift shop was good for one free passage on the bridge.[5]

It is generally believed by local residents that the Delaware Aqueduct was not maintained with the same degree of care under Kraft as it had been under Huber. In fact many residents assert that Kraft paid minimal attention to the bridge after purchasing the nearby Lackawaxen House Restaurant. This was especially true during the late 1970s when the financial welfare of Kraft's business investments began to deteriorate.

Although minor vandalism had been a problem for some years (i.e., the toll gate was sometimes removed on Halloween), such problems became more serious during Kraft's ownership--a problem that may have been the result of his hiring young people at low wages to run the toll operation. The picking up of loose planks and throwing them in the river became more prevalent and the toll house was broken into several times with windows broken.[6]

A well-publicized accident on June 23, 1977, dramatized the increasing neglect of the bridge. On that date flatbed trucks carrying heavy loads of used railroad ties had been crossing the bridge all day. In the afternoon a 1975 Ford flatbed truck with a load of

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5. "Lackawaxen Bridge, Roebling's Delaware Aqueduct, 1847," in vertical files, "Bridges," Ellenville Public Library and Museum.

6. Personal interviews with William Nieke, Jr., Minisink Ford, New York, May 5, 1983, and Orson Davis, May 5, 1983.

ties went through the deck just beyond the New York abutment, falling some 30 feet and landing on its back in the abandoned canal bed below. Neither the driver nor his assistant were hurt seriously nor was the bridge heavily damaged except for about half of the deck system of the first span on the New York side. Kraft proposed to have that portion of the deck replaced by October, when the legal aspects of the incident were unravelled.[7] While some publications viewed the accident as a result of the bridge's deterioration, a number of local residents attribute the cause of the accident to the fact that the truck was going too fast and started sliding when its brakes locked or the driver shifted gears too quickly. It is interesting to note that the plank on the span that broke had been replaced by Kraft the previous year.[8]

The bridge planking and decking were repaired by local men using a derrick to install the stringers. Some six hangers were replaced--the new ones looking considerably different from the original components, according to Arthur H. Haupt who helped with the repairs. The saddles were not damaged and thus were not replaced.[9]

After some four months the bridge was reopened to vehicular traffic. During the period of repairs the bridge was unattended on a regular basis and the historic landmark plaques were removed. On November 25, 1977, Mid-Atlantic Regional Office Landmark Specialist Peluso wrote to George Emery, Chief, Historic Sites Survey, stating that

> Mr. Kraft . . . is investing a large amount of money to restore the bridge and to clean up the entire area around the bridge

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7. "Delaware Aqueduct Deck Fails Under Gross Overload," Society for Industrial Archeology Newsletter, VI (July, 1977), 1, and The (Middletown, New York) Times-Herald Record June 24, 1977.

8. Personal interviews with Leona Davis, May 5, 1983; Orson Davis, May 5, 1983, and Arthur H. and Annabel Haupt, May 4, 1983. During the 1950s a truck carrying a 23-ton load of bricks broke one stringer on the Pennsylvania side of the bridge.

9. Personal interview with Arthur H. and Annabel Haupt, May 4, 1983.

and with the help from the grants program hopes to restore the canal, also. It is his wish that after the bridge is restored, he would like to have another ceremony and requested a replacement plaque for the occasion.[10]

Despite the criticism of Kraft's maintenance efforts at the bridge, there is some evidence that he was concerned about the upkeep of the structure. He installed new lights on the bridge and installed an electric stove in the toll house.[11] In August 1976 David Kraft cut a sample wire (with wrapping) from the main cable and gave it to Kenneth E. Nieworkne, an engineer from Bethlehem, Pennsylvania, for testing of its mechanical properties and minimum tensile strength. The tests showed that the bridge's tensile strength was undiminished and that "the wire was produced to 90,000 psi minimum tensile strength." The results of the tests were

Sample	Diameter	Tensile Strength	% R/A
Main cable	.138[6]"	93,500 psi	53.1%
Wrapping	.080 "	71,000 psi	40.1%
	.080 "	76,000 psi	

At the same time the Krafts apparently were exploring ways to protect the wires from further rusting and weathering.[12]

From 1973 to 1976 Kraft maintained the same tolls that Huber had charged--25 cents for passenger cars and 5 cents for pedestrians. In 1976, however, the tolls were raised to 50 cents for passenger cars. Kraft also introduced a new ticket system in which tickets were punched rather than torn off from a book. Despite that increase the operation of the bridge was by and large a losing proposition for the owner. The aforementioned appraisal report in April 1979 noted that

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10. Peluso to Emery, November 25, 1977, Land Resources Division Files, Mid-Atlantic Regional Office.

11. Personal interview with Orson Davis, May 5, 1983.

12. Nieworkne to Kraft, November 29, 1976, Mid-Atlantic Regional Office Files.

> It is quite doubtful that the tolls received have provided any substantial revenue for many years and ownership of the bridge is likely to be a hobby and a personal interest rather than an economic business venture.[13]

The costs and revenues of the bridge operation are more readily understood by looking at Kraft's "Yearly Operating Cost Summary" submitted to the Federal Highway Administration in February 1979. The summary included the following items:

a)	Salary of two toll collectors for ten (10) months/year, each $750/month No fee collection for 2 months): (2) (750) (10)	=	$15,000.00
b)	Total tax to two counties	=	2,200.00
c)	Electric bill for the 5 lights on bridge	=	1,200.00
d)	Upkeep (bridge maintenance)	=	1,200.00
e)	Insurance	=	850.00
f)	Snow removal	=	200.00 +
	TOTAL COST	=	$20,650.00

Kraft claimed that approximately 40,000 cars and trucks (or about 112 per day) crossed the bridge per year from which he raised $20,000 in tolls. Hence he lost some $650 per year, not counting interest payments.[14]

On April 26, 1979, an article in the New York Times reported the reminiscences of Kraft and his son James as negotiations were underway for the sale of the structure to the National Park Service. Excerpts from the article include:

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13. "Appraisal Report . . . April 16, 1979," p. 14.

14. Memorandum, Leslie L. Fugedy to Regional Director, Mid-Atlantic Region, February 26, 1979, Mid-Atlantic Regional Office Files.

"I love the bridge," Mr. Kraft says. "If I were a millionaire, I wouldn't be selling it. I'd be at the bridge for the rest of my days."

He remembers when he bought it six years ago, gulping down his beer at the Lackawaxen House bar, rushing out to stop the old man, Ed Huber, who owned it and wanted to get rid of it, and thus fulfilling a marvelous impulse.

When he made the deal and told the family, Jimmy couldn't believe they actually owned a toll bridge, just like that. He raced out onto it, running from one state to the next, from the Pocono side to the Catskill side, in joyous possession. It was theirs, lock, spans and tollhouse, replete with Barbara Neike [sic], a woman from the New York side in her ninth decade, a woman as finely wrought as the bridge, who always took time to chat as she collected the tolls.

In his time in the tollhouse, Jimmy has been threatened by boozy wise guys trying to evade to 50-cent toll. (Part of the traffic patterns involves the fact that an 18-year-old can imbibe legally here on the East bank in the Minisink Inn, while 15 seconds across the river he must wait three years to drink at the Lackawaxen House.)

Stronger than any trouble, though, is the boy's memory of the bridge's great virtues--fishing from it for eels when the spring river rose muddy; meeting an endless flow of pleasant people, including bridge buffs and scholarly engineers come to see Roebling's small masterpiece.

The modern-day traffic of 50,000 autos a year uses the same cables, suspenders, piers and anchorages put there by Roebling. The autos barely tax the bridge's anchored strength, bumping across the lumber decking that Mr. Kraft and his oldest son, David, maintained themselves.

"That's what I'll miss, sitting down and thinking about the bridge and keeping it fit," he says, referring to the 26-foot lengths of 14-inch timbers that became increasingly expensive in recent years.

"I think the U. S. came along just in time," Mr. Kraft says, his footsteps springy and thumping as a pulse beat on the bridge, which has a mesmerizing aroma of tar and time, of the water below and the trees beyond. "It was getting too expensive to run at 50 cents a car."

The Krafts plan to move away now. . . .[15]

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15. New York Times, April 26, 1979.

Although efforts were made by the author of this report to locate Albert L. Kraft for interviewing purposes, the location of his current residence could not be established. When Edward H. Huber sold the Delaware Aqueduct to Kraft in January 1973 he turned over all his records relative to the bridge to Kraft. When the National Park Service acquired the structure in March 1980 these records were not turned over as part of the transaction. Hence it is possible that these records might still be in Kraft's possession. Since they would be a valuable addition to the NPS archives on the history of the bridge, further efforts should be made to locate Kraft and acquire these materials.

CHAPTER FIFTEEN
THE DELAWARE AQUEDUCT UNDER THE NATIONAL PARK SERVICE: 1980-PRESENT

Virtually as soon as Congress authorized the Upper Delaware National Scenic and Recreational River on November 10, 1978 (Public Law 95-295, section 704), as a unit of the National Park System, agency personnel indicated a desire to acquire the Delaware Aqueduct as a "cultural resource centerpiece" for the new park. This interest coincided with the financial difficulties of Albert Kraft and his desire to sell the structure. Hence preliminary negotiations for the transfer of ownership of the structure were commenced during the winter of 1978-79.[1]

On February 13, 1979, Leslie L. Fugedy, a civil engineer of the Mid-Atlantic Regional Office, met with Federal Highway Administration officials to participate in an inspection of the bridge to determine the safety of the structure and the extent of the immediate repair work that would be required to make the bridge a safe, fully functional conduit for vehicular traffic. According to the trip report of Fugedy "close visual observations" were made

> of the structure, specifically the 8 1/2" diameter wrought iron cables, the four anchorages at the 2 abutments, the timber roadway decking and railings.
>
> The timber roadway consists of double transverse floor beams each 5" x 14", 25' long, resting on a saddle, bolted to the ends of the 1 1/4" diameter wrought iron double suspender rods on 4' centers. The floor beams are supporting the longitudinal 3" x 8" - 12' long stringers on 18" centers to which the 3" x 10" - 10' long deck planks are fastened at right angles to the direction of traffic. . . .
>
> In general, the present bridge structure is still in fair condition despite the almost criminal neglect of its maintenance for many years. The cables, anchorages and the suspender

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1. New York Times, April 26, 1979.

> rods must be repainted immediately and the wire wrapping for the cables repaired. The bridge seat on the masonry abutment at the Pennsylvania side has to be repaired, some of the timber roadway structure must be replaced and the entire railing system reconstructed in order to bring the bridge up to an acceptable safety level for both vehicles and pedestrian traffic.

The repairs which Fugedy recommended were estimated to cost $60,000.[2]

Mid-Atlantic Regional Office Director Richard L. Stanton urged on March 23 that the necessary repairs to the bridge be given first priority once the structure was acquired. Two signs were to be put up at either end of the bridge the day after title to the structure was transferred. The signs would state that the National Park Service had acquired the bridge and that the structure was considered to be unsafe. Repairs would be commenced soon, the bridge would be reopened for vehicular use, and no tolls would be charged.[3]

Meanwhile on March 12, the Federal Highway Administration had submitted a document entitled "Connection Road over Delaware River, Upper Delaware Wild and Scenic River." In the report the cost of a complete rehabilitation of the Delaware Aqueduct was estimated at $900,000. Nathan B. Golub, Associate Regional Director, Operations, Mid-Atlantic Regional Office, thus recommended that the Park Service should "take this opportunity to close the bridge to all traffic using the FHWA report as the supportive document."[4]

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2. Memorandum, Leslie L. Fugedy to Regional Director, Mid-Atlantic Region, February 26, 1979, Mid-Atlantic Regional Office Files.

3. Informal memorandum, Stanton to Golub, March 23, 1979, Mid-Atlantic Regional Office Files.

4. Memorandum, Associate Regional Director, Operations to Regional Director, Mid-Atlantic Region, March 29, 1979, Mid-Atlantic Regional Offices Files; U. S. Department of Transportation, "Bridge Safety, Federal Highway Administration, Inspection Report, Connection Road Over Delaware River, Upper Delaware Wild and Scenic River, Str. No. 4870-0018, Inspected: 2-13-79," Mid-Atlantic Regional Office Files; and Pike County Dispatch, July 12, 1979.

On April 16, 1979, W. L. Moore & Son of Easton, Pennsylvania, submitted an appraisal report of the Delaware Aqueduct to the National Park Service. The report, prepared to determine the fair market value of the structure and property, estimated the value of the land to be $10,000 and the improvements $60,000. This value estimate was to be used as the basis for acquisition of the property by the Park Service.[5]

Negotiations for the purchase of the aqueduct had proceeded far enough by April 20 that NPS Director William J. Whalen reported on their progress to the Assistant Secretary of the Interior for Fish and Wildlife and Parks. According to his memorandum of that date:

> The Mid-Atlantic Region is presently negotiating with Mr. Elbert [Albert] Kraft, a willing seller of the Delaware Aqueduct. We have hopes that this acquisition will be resolved soon. Title difficulties have surfaced and condemnation for clearing title may be required. It is being purchased under the Upper Delaware legislation as set out in the National Parks and Recreation Act of 1978.
>
> . . . The basic structure appears to be sound. A recent Federal Highway Administration inspection revealed that, with certain improvements in the roadbed and other reasonable corrections, the bridge can continue to carry light vehicular traffic with ease. At the present time a fee of 50¢ is being charged for the use of the bridge. It is used principally by people living in the small communities on either side of the river.
>
> When title to the bridge and abutments has been obtained, it is our plan to close the bridge for a brief period and undertake important corrective work. The bridge would be reopened to light traffic thereafter with no tolls being charged. Tolls are economically infeasible and minor maintenance can be handled by the present staff of the Delaware Water Gap National Recreation Area once initial repairs have been made. Local residents would be inconvenienced for several months; however, another bridge crosses the Delaware only four miles downstream.[6]

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5. "Appraisal Report . . . April 16, 1979." The report contains a section on "Income Approach to Value," which discusses the revenues and expenses arising from operation of the aqueduct. A copy of this section may be seen in Appendix P.

6. Memorandum, Director, National Park Service, to Assistant Secretary for Fish and Wildlife and Parks, April 20, 1979, Mid-Atlantic Regional Office Files.

The New York Times reported on April 26, 1979, that the "quiet mood of affection of Albert Kraft and his son Jimmy is understandable as they stroll their toll bridge and make up their minds to sell it [to] the Federal Government." The article went on to state:

> Nothing moves on the bridge this day. It has been chained closed for a month as the National Park Service negotiates to acquire the bridge and keep it for its history and beauty. Yet, a considerable deal is happening. For the bridge--Roebling's original Delaware Aqueduct--is the oldest suspension bridge in the country, and now its preservation will be guaranteed further.[7]

In May a public notice was sent to Delaware Valley residents announcing that the National Park Service "has agreed to purchase and preserve" the "Delaware Aqueduct Bridge." Regional Director Stanton stated that this action would "preserve for future visitors perhaps the most significant historical feature that remains in the area that Congress designated as the Upper Delaware Scenic and Recreational River." The bridge was to be purchased through the acquisition of stock of the Lackawaxen Bridge Company. Installation of new decking and restoration of the guard railings would take two months after the National Park Service gained ownership. The bridge would then be reopened to light vehicular traffic on a toll-free basis.[8]

The sale of the bridge was held up by a suit brought by Raymond M. Moulthrop, Jr., of Lehighton, Pennsylvania, owner of the flatbed truck that had the accident on the bridge in June 1977. Moulthrop claimed the bridge had a posted weight of 40,000 pounds, and Kraft had

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7. New York Times, April 26, 1979.

8. "Future Meetings Set for Delaware River Valley Residents," [May 1979], Mid-Atlantic Regional Office Files. This announcement was based on an "Offer to Sell" signed by all parties on May 7. It was anticipated that closing would take place in 30 to 45 days. Follow-Up Slip, Stanton to Golub/Bradford, May 7, 1979, Mid-Atlantic Regional Office Files. Also see Bert S. Feldman, "The Roebling Bridge: First Monument of the Upper Delaware," Upper Delaware Magazine, I, (Winter/Spring, 1979), 10, 40.

an obligation to maintain the bridge in strong enough condition to take that weight. The truck had a gross weight of 29,000 pounds at the time of the accident. The truck sustained damage of $8,556 and was out of service for 180 days. Thus, Moulthrop sought to recover the cost of damages plus $18,000 and interest for loss of the vehicle's use. In July 1979 Judge James Marsh of the Pike County Court in Milford directed a writ of garnishment be issued in the amount of $20,000 as a security for a possible judgment against the owner of the "Roebling Bridge." The garnishees were to be "any person, corporation or governmental agency or department that may owe money for the purchase of the Lackawaxen (Roebling) Bridge."[9]

While negotiations for the purchase of the aqueduct continued, the National Park Service was involved in various preliminary efforts to make the bridge secure. In September measurements were taken of the severely damaged suspender rods and support plates and the piers were checked for underscouring. It was determined that four suspender rods and plates be replaced after NPS acquisition of the bridge. No underscouring was observed at any of the piers but severe ice damage on the upstream face of the piers was noted.[10]

After more than 18 months of negotiations, during which time title attorneys sought to clear title questions and insure that no liens remained against the property, the Delaware Aqueduct became the property of the National Park Service on May 27, 1980, as the result of the purchase of the Lackawaxen Bridge Company for $75,000.[11] The boundary description in the deed of acquisition read:

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9. Pike County Dispatch, July 12, 1979, December 27, 1979.

10. Memorandum, Civil Engineer, Mid-Atlantic Regional Office, to Regional Director, Mid-Atlantic Region, September 19, 1979, Mid-Atlantic Regional Office Files.

11. U. S. Department of the Interior, National Park Service, News Release, "National Park Service Purchases Historic Suspension Bridge Across Delaware River," April 1, 1980, Mid-Atlantic Regional Office Files. Also see title papers relating to acquisition of the property in Land Acquisition Division Files, Mid-Atlantic Regional Office, for more details relative to the lengthy proceedings involving the purchase.

Tracts 101-01 and 101-02

[Tract numbers are those designated on Upper Delaware (N)S & RR Segment Map 101]

Tract 101-01

All that certain tract or parcel of land lying and being situated in the Town of Highland, Sullivan County, State of New York, consisting of two parcels, being more particularly described as follows:

Parcel I

BOUNDED westerly by the easterly end of the aqueduct formerly carrying the Delaware and Hudson Canal over the Delaware River known as the Delaware and Hudson Canal Aqueduct; bounded easterly by the easterly line of lands of said party of the first part, which is a line drawn parallel with and distant 15 feet easterly from the Delaware and Hudson Canal and bounded northerly and southerly by lines drawn parallel with and distant 15 feet (measured at right angles) northerly and southerly respectively, from a line which would be an easterly extension of the centerline of said aqueduct; together with so much of the Delaware and Hudson Canal Aqueduct aforesaid as now constructed and existing across the Delaware River from a point in said Town of Highland to a point in the Township of Lackawaxen, County of Pike and State of Pennsylvania, as is located in said Town of Highland and State of New York; together with the side roadways attached thereto and forming a part of said portion of said structure and the wire cables, anchorages, supports, masonry, piers and abutments supporting said portion of said structure and all other appurtenances thereof; together with the land adjacent to the river occupied by said portion of said structure and its appurtenances and any and all rights, franchises and easements to operate and maintain the said aqueduct and its appurtenances across and over said river.

BEING a portion of the same premises which Charles Spruks and Nettie Spruks, his wife, by their certain deed dated November 1, 1930 and recorded in the Sullivan County Clerk's Office in Liber 276 of Deeds, at Page 580, on December 10, 1930, granted and conveyed unto the Lackawaxen Bridge Company.

Parcel II

COMMENCING at the intersection of the centerline of the highway leading across the Delaware River to the hamlet of Lackawaxen, Pennsylvania and the westerly right-of-way line of State Highway 97; thence South 27° 27' East, 53 feet, more or less, to an iron pin and the point of beginning; thence South 62° 33' West, 39.0 feet to an iron pin; thence South 27° 27' East, 22.0 feet to an iron pin; thence South 62° 33' West, 142.0 feet to an iron pin; thence North 27° 27' West, 145.0 feet to an "X" chiseled in rock; thence North 62° 23' East, 181.0 feet to an iron pin set on the westerly bounds of said State Highway 97; thence South 27° 27' East, along said right-of-way, 123.0 feet to the point of beginning.

Parcel II containing 0.58 of an acre, more or less.

Said Parcel II being the same land as depicted on a plat entitled "Map Showing Lands of Lackawaxen Bridge Co." prepared by John Kestler, Land Surveyor Lic. No. 35418, dated July 3, 1963 and being a portion of the same premises which Charles Spruks and Nettie Spruks, his wife, by their certain deed dated November 1, 1930 and recorded in the Sullivan County Clerk's Office in Liber 276 of Deeds, at Page 583, on December 10, 1930, granted and conveyed unto the Lackawaxen Bridge Company.

Tract 101-02

All that certain tract or parcel of land lying and being situated in Lackawaxen Township, Pike County, State of Pennsylvania, consisting of two parcels, being more particularly described as follows:

Parcel I

CONSISTING of a strip of land 30 feet wide, bounded easterly by the westerly end of the aqueduct, formerly carrying the Delaware and Hudson Canal over the Delaware River and known as the Delaware and Hudson Aqueduct; bounded westerly by a line, described in deed of Erie and Wyoming Valley Railroad Company to Charles Spruks dated May 12, 1908 as, "the westerly line of lands of said party of the first part," which is a line drawn parallel with and distant 15 feet westerly from the Delaware and Hudson Canal, and bounded northerly and southerly by lines drawn parallel with and distant 15 feet (measured at right angles) northerly and southerly, respectively, from a line which would be a westerly extension of the centerline of said aqueduct, together with so much of the Delaware and Hudson Canal aqueduct aforesaid as now constructed and existing across the Delaware River from a point in the Town of Highland, in the County of Sullivan and State of

New York, to a point in the said Township of Lackawaxen, as is located in said Township of Lackawaxen and State of Pennsylvania; together with the side roadways attached thereto and forming a part of said portion of said structure, and the wire cables, anchorages, supports, masonry, piers and abutments supporting said portion of said structure and all other appurtenances thereof; together with the land adjacent to the river occupied by said portion of said structure and its appurtenances and any and all rights, franchises and easements to operate and maintain the said aqueduct and its appurtenances across and over said river.

Parcel I containing 0.14 of an acre, more or less.

BEING the same premises which Charles Spruks and Nettie Spruks, his wife, by their certain deed dated November 1, 1930 and recorded in the Office of the Recorder of Deeds in and for Pike County, Pennsylvania, in Deed Book Volume 84, at Page 386, on December 4, 1930, granted and conveyed unto the Lackawaxen Bridge Company.

Parcel II

BEGINNING at a point formed by the intersection of a line parallel to the abandoned Delaware and Hudson Canal and distant 15 feet southerly from the berme side of same and the property line, now or formerly of said William C. Cortright and one Anna C. Gregory; and running thence North 39° West 41 links (27.06') to southeasterly edge of a small stone retaining wall; thence South 48 3/4° West 1 chain and 61 links (106.26') along edge of said wall to the center of the highway leading from the Lackawaxen Post Office past the residence, now or formerly, of said William C. Cortright; thence along center of said highway, South 24 1/4° East 25 links (16.5'); thence North 54 3/4° East 1 chain and 68 links (110.88') along lands, now or formerly, of said Anna C. Gregory to the place of beginning.

Containing 0.05 of an acre, more or less.

Said Parcel II being a portion of the same land as depicted by a plat entitled "Map of Land showing premises surveyed for the Lackawaxen Bridge Company, Inc." prepared by John A. Boehm, Registered Surveyor, Greely, [sic] Pennsylvania, dated April 25, 1974, Dwg. No. A21-134. Said Parcel also being conveyed by William C. Cortright and Jerusha W. Cortright, his wife, to Charles Spruks by deed dated September 13, 1921 and recorded in Deed Book 73 at Page 305 of Pike County.[12]

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12. Deed, Lackawaxen Bridge Company to United States of America, dated March 27, 1980, Pike County Deed Book 714, Folios 283-87, and Sullivan County Deed Book 959, Folios 121-25. Boundary survey maps for Tracts 101-01 and 101-02 may be seen on the following pages.

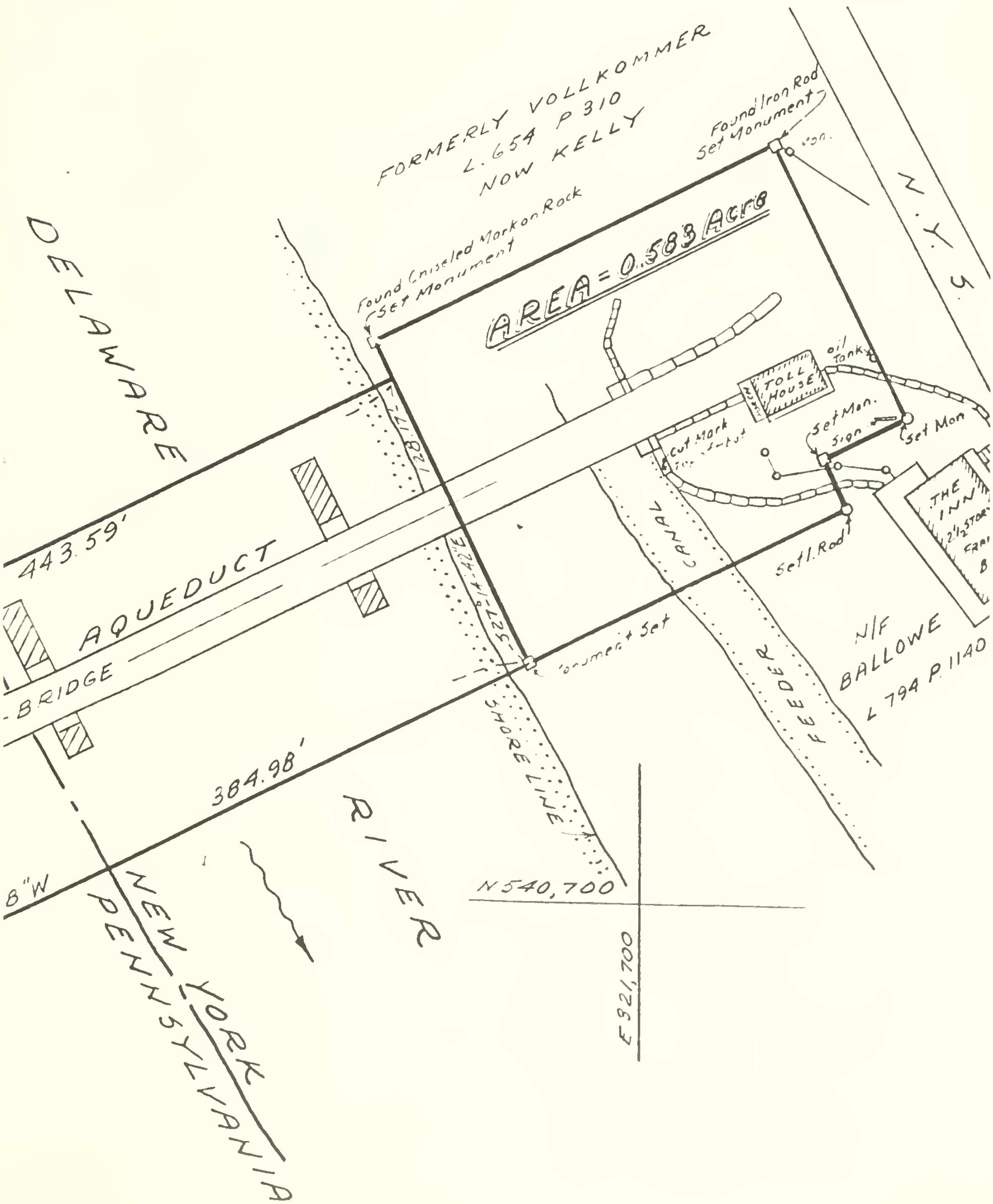
101-01

SCALE: 1" = 50'

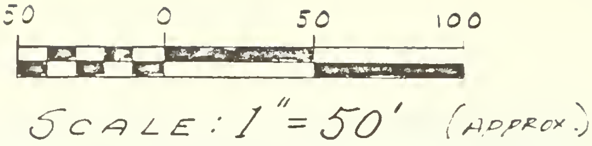
50 0 50 100

PREPARED	TITLE OF DRAWING	DRAWING NO
J.C.W.	BOUNDARY SURVEY MAP	
DESIGNED	LOCATION WITHIN PARK	PKG. NO. / SHEET
W.E.W	NEW YORK & PENNA. APPROACHES TO THE DELAWARE AQUEDUCT	3
DRAWN	NAME OF PARK	
J.C.W.	UPPER DELAWARE NATIONAL SCENIC AND RECREATIONAL RIVER. NSRR	
CHECKED	MID-ATLANTIC (REGION) / PIKE & SULLIVAN (COUNTY) / NEW YORK PENNA. (STATE)	OF 3
11-29-80		
DATE		

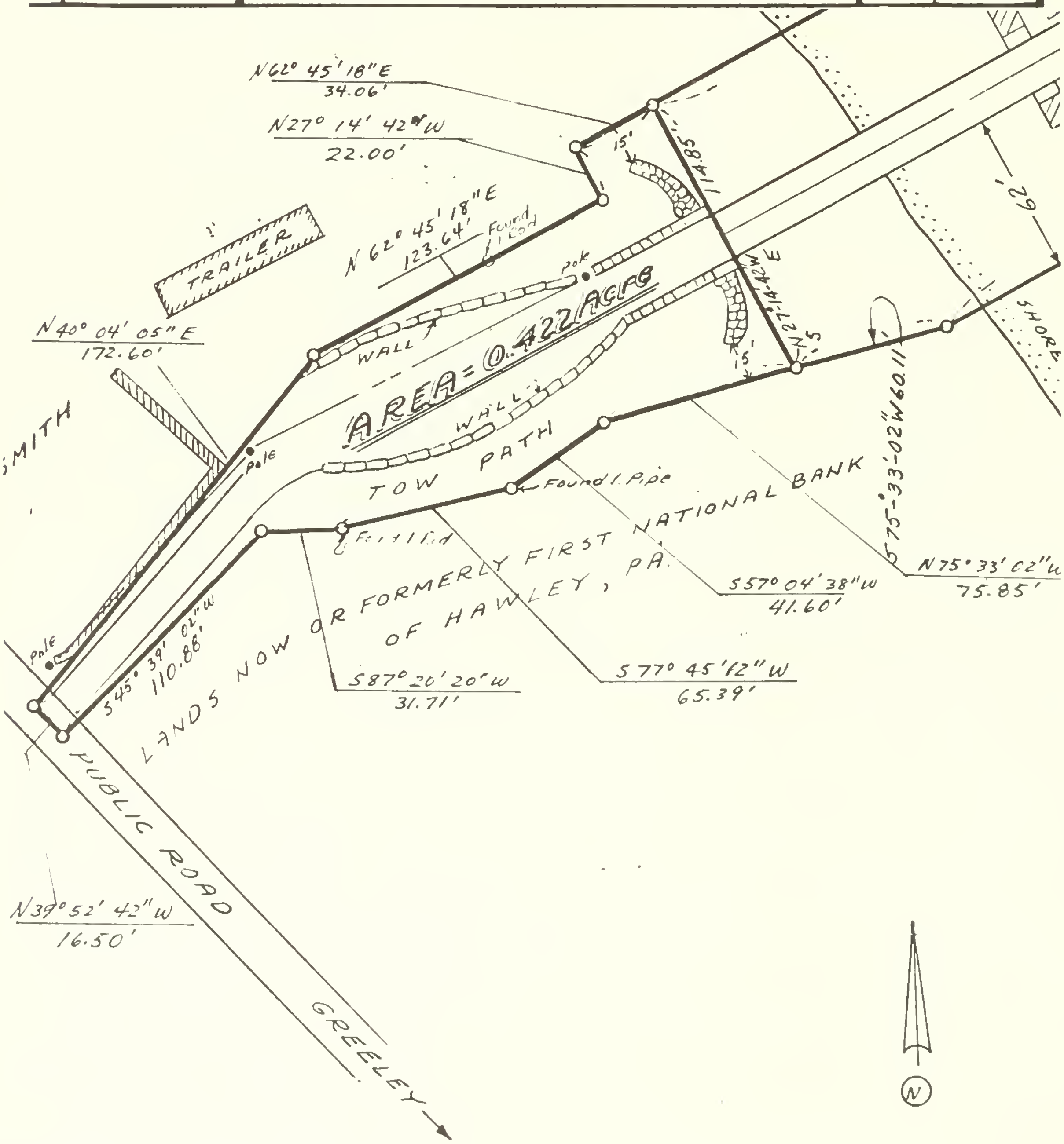
☆ GPO 1977-780 28



101-02



PREPARED	TITLE OF DRAWING	DRAWING NO.
J.C.W.	BOUNDARY SURVEY MAP	——
DESIGNED	LOCATION WITHIN PARK	PKG. NO. / SHEET
W.E.W.	NEW YORK & PENNA. APPROACHES TO THE DELAWARE AQUEDUCT	3
DRAWN	NAME OF PARK	
J.C.W.	UPPER DELAWARE NATIONAL SCENIC AND RECREATIONAL RIVER. NSRR	
CHECKED	MID-ATLANTIC (REGION) / PIKE & SULLIVAN (COUNTY) / NEW YORK PENNA. (STATE)	OF 3
11-29-80		
DATE		



When it was determined that there were certain errors in the deed pertaining to Tract 101-02 on the Pennsylvania side of the aqueduct a correction deed was filed on March 16, 1981, to amend the original deed. The revised boundary description read:

Tract 101-02

> All that tract or parcel of land situate in the Township of Lackawaxen, Pike County, State of Pennsylvania, lying on the westerly side of the Delaware River, and is more particularly bounded and described as follows:
>
> BEGINNING at a point in the center of the public highway leading through Lackawaxen, said point being the northwesterly corner of lands of the First National Bank of Hawley (Liber 249, Page 181); North 39° 52' 42" West, along the center of said highway, 16.50 feet to a point; thence North 40° 04' 05" East, along the southeasterly edge of a low stone retaining wall and an extrapolation thereof, 172.60 feet to a monument set; thence North 62° 45' 18" East, along lands now or formerly of Smith, 123.64 feet to a point; thence North 27° 14' 42" West, 22.00 feet to a point; thence North 62° 45' 18" East, 34.06 feet to a point; thence South 27° 14' 42" East, along the easterly face of the west abutment of the Delaware Aqueduct, 114.85 feet to a point; thence North 75° 33' 02" West, along the south side of a tow path, 75.85 feet to an iron rod; thence South 57° 04' 28" West, along said tow path, 41.60 feet to an iron pipe found; thence South 77° 45' 12" West, along said tow path, 65.39 feet to an iron rod found at the end of the tow path; thence South 87° 20' 20" West, 31.71 feet to a monument set; thence South 45° 39' 02" West, 110.88 feet to the place of beginning.
>
> Containing 0.42 of an acre of land as surveyed by Joseph C. Woods, P.L.S. in November, 1980, a copy of said survey being attached hereto and made a part hereof.
>
> Subject to electric company rights and easements, telephone company rights and easements, and public highway easements and dedications of record, if any.[13]

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13. Deed of Correction, Lackawaxen Bridge Company to United States of America, dated March 16, 1981, Pike County Deed Book 772, Folios 56-60. Also see Memorandum, Chief, Acquisition Branch, Land Resources Division, Mid-Atlantic Regional Office, to Superintendent, Upper Delaware Scenic and Recreational River, January 27, 1983, Land Resources Division Files, Mid-Atlantic Regional Office, for notification of closing and passage of title of property to National Park Service.

The National Park Service issued a press release on April 1 announcing the purchase of the Delaware Aqueduct. Excerpts from the press release include:

> The National Park Service has completed the purchase of the Delaware Aqueduct Bridge that spans the Upper Delaware River between New York and Pennsylvania. . . .
>
> The old bridge, long ago converted from canal boats to cars, was purchased through the acquisition of the stock of the Lackawaxen Bridge Company, owned by Albert Kraft and his family of Hawley, PA.
>
> NPS reached agreement with the company last summer to purchase the bridge. Purchase was delayed while title attorneys insured that no liens remained against the property.
>
> Until recently, the bridge was one of the last privately operated bridges in the eastern seaboard. Some 50,000 vehicles a year used the bridge; the toll was 50 cents a car. It was closed by the owner in the spring of 1979 after vandalism made the span unsafe.
>
> "We will take immediate steps to determine the soundness of the bridge," said James W. Coleman Jr., Acting Regional Director of the Mid-Atlantic Region headquarters in Philadelphia.
>
> "We have made our own engineering study. Now we must consult with federal highway engineers on the bridge's safety. After a thorough inspection, the Federal Highway Administration will determine whether the bridge can be reopened to either pedestrian or light vehicular traffic."
>
> In the meantime, Coleman emphasized, the bridge is closed to the public.
>
> The Delaware Aqueduct Bridge is an important historical feature of the Upper Delaware Scenic and Recreational River. . . .
>
> The Park Service also plans to install an interpretive exhibit at either end of the bridge. The display will tell visitors of the engineering and technological history of the bridge, of its function as part of the Delaware and Hudson Canal system and give a profile of its builder.[14]

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14. U. S. Department of the Interior, National Park Service, Press Release, April 1, 1980, Mid-Atlantic Regional Office Files.

The National Park Service quickly took steps to reopen the bridge to pedestrians. On April 22 a survey was made of the bridge to determine the amount of lumber needed to make temporary repairs. All deck-planks, railings, and railing posts that needed replacement to make the structure safe for pedestrian traffic were counted. It was noted that there were "many large gaps on the bridge because of missing 3" x 10' deck planks that were either thrown into the river or simply carried away by vandals. This made it extremely dangerous for anyone to walk, drive or bicycle on the bridge." After this repair work would be completed the Park Service would be able "to use a small truck mounted crane on the bridge to lift up the heavy cast-iron pier-caps over the support cables to be checked" when the Federal Highway Administration reinspected the bridge. It was found that the following lumber material was needed:

442 deck-planks @ 3" x 8" - 10' long	=	8,840 bd. ft.
61 railing posts @ 4" x 8" - 6' long	=	488 bd. ft.
2034 lin. ft. of 6" x 1" railings	=	1,018+ bd. ft.
TOTAL	=	10,346 bd. ft. [15]

While the National Park Service was making plans to let a contract for the temporary repairs the condition of the bridge and the prospects for renewed vehicular traffic over the span were described in an article in the Pike County Dispatch on August 14. Among the "deficiencies" were "missing decking and railing, with the rest described as '80 percent rotten.' Other problems included a chain used to replace a deck supporting rod, rusted cables and anchor bolts, broken and frayed cable wire, ice-damaged masonry piers bulging out in places. . . ." These problems, the result of deferred maintenance, made it unlikely that vehicular traffic would be commenced anytime soon. The writer concluded by observing that "highway usage in itself has become regarded as a 'historical right' by Lackawaxen residents, who are becoming increasingly

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15. Memorandum, Civil Engineer, Mid-Atlantic Regional Office, to Acting Regional Director, Mid-Atlantic Region, May 5, 1980, Mid-Atlantic Regional Office Files. It was noted that at the present time the bridge was "closed to pedestrian and vehicular use by chain-link gates installed by the Park at both ends of the bridge and by heavy guardrails constructed by the New York State Highway Department."

impatient at having to detour through Shohola or Narrowsburg to cross the Delaware River."[16]

A contract for "Repair Work on Roebling Bridge" was let to Bonham's General Contracting of Honesdale, Pennsylvania, and work began on August 20. The contract called for repairing and replacing portions of the deck, constructing new railing, and replacing four damaged suspender rods at a cost of $9,241.25.[17] When the contractor commenced work by removing deteriorated, unsalvageable deck planks and long-decayed railings it was found that those railing posts which the National Park Service had wanted to save were also badly deteriorated. Thus it was determined to replace all posts and install new ones with new bolts and bracing. A contract was also let to Kevin Marrinan of Eldred, New York, to rework the electric lighting on the bridge.[18]

When the aforementioned work was underway the Federal Highway Administration inspected the bridge on August 27. Some general observations resulting from the inspection were:

> Based on an evaluation of rating factors given in the report, this structure is appraised to be in critical condition. At the time of this inspection, the bridge was closed to all traffic and was receiving minimal timber repairs in order to open the bridge to pedestrian traffic only. Since all of the timber decking was being removed in the repair process, a thorough inspection of the timber stringers and floor beams was performed.
>
> Several timber floor beams were found to be undersized (i.e. 4" x 14" rather than 5 1/2" x 14") and major deterioration and horizontal shear failure cracks were observed at random locations throughout the bridge. Several timber stringers exhibited tensile failures at midspan which developed into shear

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16. Pike County Dispatch, August 14, 1980.

17. A copy of the original contract bid schedule may be seen in Appendix Q.

18. Memorandum, Civil Engineer, Mid-Atlantic Regional Office, to Regional Director, Mid-Atlantic Regional Office, September 18, 1980, Mid-Atlantic Regional Office Files, and River Reporter, November 6, 1980.

failures as the crack approached the neutral-axis of the stringer. Severe decay and fungus attack was observed on many of the timber stringers and floor beams. The majority of the timber stringers exhibited sway and negative camber. Many members contained large knots which were located in the tension area of the beams and stringers. These knots effectively reduce the depth of the member by the knot diameter, thus reducing the available strength of the member to carry live loads. All timber used in this bridge appears to be mill run lumber. In order to allow vehicular traffic on this bridge, all existing timber will have to be replaced with structural grade lumber, appropriately sized by the desired live loading.

As to the overall condition of the bridge, the report stated that there was critical "timber deck, stringer, and floor beam deterioration; 90% of railing missing; cable strand deterioration; several hangers damaged; masonry joint deterioration; ice damage to piers." The cables were in poor condition: "30% deterioration of covering, approximately 15% of cable strands are broken and rusting." The hangers were in fair condition with "one missing and replaced with [a] chain, [and] several bent." After "all the temporary timber repairs" had been made "to open the bridge for pedestrian traffic" the "estimated remaining life" [of the structure] could "be increased to 1 year." Accordingly, Federal Highway Administration officials recommended that all iron members be cleaned, repaired, and painted, all timber members be replaced with treated timber, and all masonry joints be cleaned and pointed with missing stones to be replaced. The estimated cost of all these improvements was $900,000, although the estimated cost of the most critical repairs to permit reopening of the bridge to light vehicular traffic (up to six tons) was $450,000.[19]

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19. U. S. Department of Transportation, Federal Highway Administration, "Bridge Safety Inspection Report, Connection Road Over Delaware River, Upper Delaware Wild and Scenic River, Str. No. 4870-001P, Inspected: 8-27-80"; U. S. Department of the Interior, National Park Service, News Release, "Highway Agency Evaluates Delaware Aqueduct As In 'Critical Condition,'" November 13, 1980, Mid-Atlantic Regional Office Files; Pike County Dispatch, December 14, 1980.

After completion of the temporary deck repairs the bridge was reopened to pedestrian and bicycle traffic on October 23. To assure safe access to the structure, 4-foot-wide "gap gates" were constructed at both ends of the aqueduct. Blacktop trails from both guardrail gates at the ends of the aqueduct were also constructed. Protective and informative signs were installed at both ends of the structure, and measures were taken to insure that the park would maintain a clear and safe pathway over the aqueduct free of snow and ice during the winter.[20]

Meanwhile, a petition signed by five hundred local residents was presented to the National Park Service at a public meeting held at Lackawaxen on October 29, 1980, requesting the reopening of the bridge to vehicular traffic. In responding to this petition, as well as the Federal Highway Administration report, Mid-Atlantic Regional Director James W. Coleman, Jr., observed:

> We have just spent $26,000 on the aqueduct to replace rotted timbers, install new decking and railing, and restore the lighting. . . . These were makeshift repairs that will allow pedestrians and bicyclists to use the old bridge and use it in safety. . . . To get the funds to make these repairs, we had to divert money from other park programs. . . . We are well aware of the desire of many people in the Upper Delaware Valley to allow cars and trucks to use the bridge again. At the same time, I'm sure people realize that the high cost of accomplishing this would make it difficult to add it to the Park Service budget. . . . We are also concerned about the historic integrity of the aqueduct. I have asked the regional historian to evaluate the historic significance of the structure and to make recommendations as to how modern-day traffic can be compatible with the historic appearance that we purchased the bridge to preserve.[21]

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20. Memorandum, Civil Engineer, Mid-Atlantic Regional Office, to Regional Director, Mid-Atlantic Regional Office, September 18, 1980, Mid-Atlantic Regional Office Files; River Reporter, November 6, 1980.

21. U. S. Department of the Interior, National Park Service, News Release, "Highway Agency Evaluates Delaware Aqueduct As In 'Critical Condition,'" November 13, 1980, Mid-Atlantic Regional Office Files.

The resource management problems associated with the Delaware Aqueduct continued to pose serious questions for the National Park Service. Various local citizens groups went on record as advocates for reopening the aqueduct to vehicular traffic, while at the same time estimates of rehabilitating the structure for such purposes were nearly $1,000,000. The resource management problems, as stated by Superintendent John T. Hutzky, on November 13, 1980, were two-fold:

> . . . the primary problem is preservation of an historic structure that is one of the prime cultural resources of the river valley, and the second problem is to resolve the long term use of the structure as a result of the political pressure to mandate its future as a vehicle crossing.

Accordingly, he requested that three research projects be undertaken to "evaluate the preservation needs and the long term status of the Roebling Aqueduct": studies of the extant remains of the Delaware and Hudson Canal, structural analysis of the cable suspension system and masonry supporting structures of the bridge, and the long-term effects of continued use of the aqueduct as a vehicular bridge as opposed to remaining as a pedestrian crossing.[22]

Later on March 3, 1981, the Cultural Resources Workgroup of the Upper Delaware General Management Planning Team prepared a draft report on the problems facing the National Park Service relative to the utilization of the Delaware Aqueduct. With Sandra Hauptman, Mid-Atlantic Regional Office Outdoor Recreation Planner, as leader, this workgroup noted some of the difficulties associated with this issue:

> The National Park Service is committed by its own cultural resource management policies to preserve the historic materials, configuration, and integrity of the structure. Simply put, the question is, will reopening the bridge to vehicular traffic

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22. Memorandum, Superintendent, Upper Delaware NS & RR, to Regional Director, Mid-Atlantic Region, November 13, 1980, Mid-Atlantic Regional Office Files. Also see Memorandum, Team Captain, Upper Delaware Planning Team to Regional Director, Mid-Atlantic Region, March 3, 1981, and Castleberry to Collins, September 4, 1981, Mid-Atlantic Regional Office Files.

compromise the structure's historic fabric and values, accelerate deterioration or otherwise harm the structure? To answer this question, technical information and studies are required to assess the condition of the cables, to evaluate the impact of sway and vibrations that are caused by vehicular use and to answer other preservation questions. . . .

Returning the bridge to vehicular use would preclude the interpretive option of using the existing toll house as a "museum" because people could not safely walk to it. The bridge is worthy of interpretation, and in order to provide this service to park visitors, other means would have to [be] explored.

Regardless of whether or not the bridge can be reopened for vehicular use, it is in urgent need of immediate repairs to the cables to stabilize them and to prevent further deterioration. The masonry piers also require repair and stabilization as soon as possible. To perform these two tasks $500,000 is needed. . . .

Should research indicate that the Aqueduct can, without compromising its historic values, be reopened to vehicular use, the Federal Highway Administration would have to be consulted. Safety standards would have to be met in a way that enables the bridge to retain its historic appearance.

An analysis of the options for reopening the bridge to automobile traffic indicates that there appear to be three choices.

1. Replacing the wooden members of the present suspension bridge system which was installed in 1933. Under this system the roadway is entirely supported by the cables. (The design weight for the cables is 3870 tons which is more than a hundred times in excess of what would ever be required for vehicular traffic.)

2. Reconstructing the trunk system which existed for 85 years (50 years for the canal and 35 years as a roadway). Under this system, the roadway would not depend entirely on the cable system for its full load-bearing capability.

3. Using new technology such as an orthotropic steel deck to which the cables could be attached in a no-load condition. Modern steel elements could be covered with wood.

> Cost estimates has [have] yet to be developed for these three options, but funding would be needed in excess of the $500,000 which will be needed for stabilization of the cables and piers.[23]

On August 25 NPS personnel met with Regional Director Coleman to explore the options for the future of the Delaware Aqueduct, develop a Park Service position on the treatment of the structure, and plan strategy for future programming. The following conclusions were reached:

1. "The Park Service is committed to the preservation of the historic elements of the structure and we will take the actions needed to stabilize the cables and masonry. . . ."

2. "The National Park Service is committed to opening the bridge for light vehicles. However, before we can request funding for the repairs needed to reopen the bridge to vehicular traffic, we have to thoroughly explore the possibilities of shared or cooperative management. . . ."[24]

In October 1982 the National Park Service published its long-awaited "Draft Environmental Impact Statement for the River Management Plan" of Upper Delaware National Scenic and Recreational River. Relative to the cultural resource management of the Delaware Aqueduct it stated:

> The Delaware Aqueduct is listed on the National Register of Historic Places. The Park Service owns the structure and is committed to preserving its significant elements, in accordance with "NPS-28, Cultural Resources Management Guideline." A detailed engineering study is in progress to determine if the bridge can be reopened to light vehicular and pedestrian use without threatening its historic integrity. The bridge will be

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23. Part III.B. Cultural Resources Workgroup Report (Draft), March 3, 1981, Mid-Atlantic Regional Office Files.

24. Memorandum, Outdoor Recreation Planner to Regional Director, Mid-Atlantic Regional Office, September 3, 1981. See Memorandum, Outdoor Recreation Planner to Regional Director, Mid-Atlantic Region, August 21, 1981, Mid-Atlantic Regional Office Files, for background data of this meeting. One such meeting to be held with local Delaware Valley citizens' groups and political interests in the aftermath of the August 25 statement was held at the Zane Grey House at Lackawaxen, Pennsylvania, on September 18, 1981. See "Roebling Bridge Meeting, Zane Grey House, Lackawaxen," September 18, 1981, Mid-Atlantic Regional Office Files, for the minutes of this meeting.

> reopened only if the engineering study indicates that the historic fabric will not be harmed. The actual reopening will depend on funding.
>
> The possible role that the towns, counties, and two states might play in sharing some of the operational and maintenance costs of the aqueduct should be further explored. . . .
>
> The aqueduct's national significance will continue to be interpreted and put into historic perspective for the public through exhibits, signs, and programs. Specifically, the tollhouse at the east end of the aqueduct may be adaptively used for wayside exhibits in a mini-museum.[25]

The engineering study referrred to in the "Draft Environmental Statement" was submitted to the National Park Service by A. G. Lichtenstein & Associates, Inc., of Fair Lawn, New Jersey, that same month. The firm had performed various field inspections and tests on the bridge's structural elements to determine its load carrying capability and the amount of stiffening needed to stabilize the deck and roadway to insure low maintenance operation.[26] The overall conclusions contained in the report were:

> 1. The present utilization of the Bridge as a pedestrian crossing is structurally adequate without the addition of a stiffening truss. However, maintenance work should be performed on several floorbeams and stringers as well as protection and painting of the cables.
>
> 2. The Bridge can be reopened to limited highway traffic <u>after</u> certain structural upgrading work is performed as discussed in this Report.
>
> 3. In our opinion this upgrading work can be accomplished without compromising the historic elements of the Bridge and in an economical manner.

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25. U. S. Department of the Interior, National Park Service, "Draft Environmental Impact Statement for the River Management Plan, Upper Delaware National Scenic and Recreational River," October 1982, p. 88.

26. U. S. Department of the Interior, National Park Service, Denver Service Center, "Our Scenic Delaware," October 1982, p. 3.

4. The recommended highway traffic should be limited to one lane and to vehicles not exceeding 15 tons in weight. This should suffice for community services such as fire trucks, school busses, ambulances, etc.

5. The estimated cost of the upgrading construction is $800,000 in 1983 dollars. This does not include engineering, legal services, approach work, traffic devices and Right-of-Way costs.[27]

In late 1982 Congress, at the urging of Representative Joseph M. McDade of the 10th Congressional District of Pennsylvania, approved the expenditure of $391,000 for the rehabilitation of the Delaware Aqueduct during fiscal year 1983. The figure was broken down into three specific categories: $115,000 for bridge cable repairs; $250,000 for architectural-engineering contract for preliminary design work and construction drawings for stabilization/preservation of structure; and $26,000 for preparation of historic structure report on bridge by NPS personnel.[28]

In early 1983 the National Park Service initiated two studies on the Delaware Aqueduct. A contract was let to A. G. Lichtenstein & Associates, Inc., to establish the original configuration and materials of the bridge's cable suspension system and piers and determine the best methodology for the stabilization/preservation of those components. National Park Service personnel in both the Mid-Atlantic Regional Office

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27. "Delaware and Hudson Canal Bridge Over the Delaware River at Lackawaxen, Rehabilitation Study (For Vehicular Loading), October, 1982," Prepared for U. S. Department of the Interior, National Park Service, Mid-Atlantic Region, Submitted by: A. G. Lichtenstein & Associates, Inc., Consulting Engineers, p. 2. The report contained sections on the inspection results, cable system analysis, load testing, and design for rehabilitation. Excerpts from the report may be seen in Appendix R.

28. Pike County Dispatch, February 10, 1983.

and the Denver Service Center were assigned to prepare an historic structure report, this document being one section of that report.[29]

A ceremony was held at the Delaware Aqueduct during the afternoon of June 4, 1983, to replace and rededicate its National Historic Landmark plaques. The unveiling of the new plaques (to replace the ones stolen from the aqueduct some years earlier) was the climax of a day-long symposium honoring John A. Roebling and his contributions to bridge engineering technology sponsored by the Center for Canal History and Technology in Easton, Pennsylvania.[30]

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29. Memorandum, Park Planner Hauptman to Associate Regional Director Bond, February 14, 1983; Memorandum, A. G. Lichtenstein to Sandra Hauptman, Project Manager, March 3, 1983; and U. S. Department of the Interior, National Park Service, "National Park Service Takes Steps to Restore Delaware Aqueduct Bridge," n.d.; Mid-Atlantic Regional Office Files. Also see Pike County Dispatch, February 17, 1983; The (Middletown, New York) Times-Herald Record, March 19, 1983; and The Pocono Record, February 6, 1983.

30. (Draft) Coleman to McDade, n.d., Mid-Atlantic Regional Office Files; River Reporter, May 5-18, 1983; and "John A. Roebling Symposium, June 4, 1983, Sparrow Bush, New York."

RECOMMENDATIONS

Virtually all known repositories having materials relating to the Delaware Aqueduct were consulted or visited during the course of research of this report. It is recommended, however, that Upper Delaware National Scenic and Recreational River establish an oral history program and tape record interviews with many of the persons named in this study who have had some affiliation with the maintenance and operation of the Delaware Aqueduct. As a beginning focal point for the oral history program it is recommended that the following persons be interviewed: Edward H. Huber, Carl A. Draxler, Arthur H. and Annabel Haupt, Orson and Leona Davis, and Olive Brower Finenko.

It is also recommended that the National Park Service acquire the original Weston maps of the Delaware and Hudson Canal presently located at the Delaware and Hudson Railway Company in Albany, New York. If this is not possible or practical, the maps should be obtained by an organization such as the Center for Canal History and Technology in Easton, Pennsylvania.

Efforts should be made to locate Albert L. Kraft for interviewing purposes and for possible acquisition of any Lackawaxen Bridge Company records still in his possession for the NPS archives at Upper Delaware National Scenic and Recreational River.

REPOSITORIES VISITED DURING RESEARCH

Albany Institute of Art and History, Albany, New York

Albany Public Library, Albany, New York

Crawford Memorial Library, Monticello, New York

Delaware and Hudson Canal Historical Society, High Falls, New York

Delaware and Hudson Railway Company, Albany, New York

Ellenville Library and Museum, Ellenville, New York

Free Library of Philadelphia, Philadelphia, Pennsylvania

Historical Society of Pennsylvania, Philadelphia, Pennsylvania

Library of Congress, Washington, D. C.

Mid-Atlantic Regional Office, National Park Service, Philadelphia, Pennsylvania

Minisink Valley Historical Society, Port Jervis, New York

New York State Archives, Albany, New York

New York State Library, Albany, New York

Pike County Courthouse, Milford, Pennsylvania

Pike County Historical Society, Milford, Pennsylvania

Pike County Public Library, Milford, Pennsylvania

Port Jervis Free Library, Port Jervis, New York

Rensselaer Polytechnic Institute, Troy, New York

Rutgers University (Alexander Library and Library of Science and Medicine), New Brunswick, New Jersey

The Wayne Independent, Honesdale, Pennsylvania

Wayne County Historical Society, Honesdale, Pennsylvania

Wayne County Public Library, Honesdale, Pennsylvania

State University of New York (Sojourner Truth Library), New Paltz, New York

Sullivan County Courthouse, Monticello, New York

REPOSITORIES CONSULTED DURING RESEARCH

American Philosophical Society, Philadelphia, Pennsylvania

Engineering Societies Library, New York, New York

Free Public Library, Trenton, New Jersey

Mayo Lynch & Associates, Inc., Hoboken, New Jersey

National Archives, Washington, D. C.

New Jersey Historical Society, Newark, New Jersey

New York Canal Society, Syracuse, New York

New-York Historical Society, New York, New York

Pennsylvania Historical and Museum Commission, Harrisburg, Pennsylvania

Sullivan County Democrat, Callicoon, New York

Sullivan County Historical Society, Hurleyville, New York

The Franklin Institute, Philadelphia, Pennsylvania

CHAIN-OF-TITLE FOR DELAWARE AQUEDUCT:

1899 - PRESENT

June 24, 1899	-	Delaware and Hudson Company to Cornell Steamboat Company (Orange County Deed Book 453, Folio 63)
November 11, 1899	-	Cornell Steamboat Company to Erie and Wyoming Valley Railroad (Pike County Deed Book 62, Folios 351-53)
December 11, 1899	-	Cornell Steamboat Company to Delaware Valley and Kingston Railway Company (Sullivan County Deed Book 133, Folios 87-90)
May 12, 1908	-	Erie and Wyoming Valley Railroad to Charles Spruks (Pike County Deed Book 62, Folios 351-53)
May 12, 1908	-	Delaware Valley and Kingston Railway Company to Charles Spruks (Sullivan County Deed Book 155, Folios 48-49)
November 1, 1930	-	Charles Spruks and Nettie Spruks to Lackawaxen Bridge Company (subsidiary of Federal Bridge Company) (Pike County Deed Book 84, Folios 386-88)
June 1, 1942	-	Purchase of Lackawaxen Bridge Company by Edward H. Huber (transfer of company stock; no land deed recorded)
January 15, 1973	-	Purchase of Lackawaxen Bridge Company by Albert L. Kraft (transfer of company stock; no land deed recorded)
March 27, 1980	-	Lackawaxen Bridge Company to United States of America (Pike County Deed Book 714, Folios 283-87, and Sullivan County Deed Book 959, Folios 121-25)

APPENDIXES

APPENDIX A

Description of Delaware and Hudson Canal by Henry S. Tanner, 1840

DELAWARE AND HUDSON CANAL, unites the Hudson river with the Carbondale coal mines, in Pa. It commences on the left bank of the Walkill, at Eddyville, about 2 miles south of Kingston, and proceeds in a general southwest direction, along the valleys of the Walkill, Rondout, Butterkill and Nevisink rivers, and through Kingston, Marbletown, Mombacus, and Warwasing, in Ulster county, to Port Jervis, at Carpenter's Point, on the Delaware. At this point the canal deflects towards the northwest and pursues that course, along the left bank of the Delaware, to a dam near the mouth of the Lackawaxen creek; here the canal crosses the Delaware, and enters the valley of the Lackawaxen, which is thence followed along its north declivity, to Honesdale, where it terminates, and where the rail-road to Carbondale commences.

The rail-road section of this improvement, 16.50 miles in length, has a rise towards the summit of 912 feet, and thence to the coal mines it descends 850 feet, overcome by 7 inclined planes, with an inclination of one in twelve. Length of the New York section of the canal, 83 miles; Pennsylvania section, 25 miles; and rail-road, 16.50 miles; total length from the Hudson to Carbondale, 124.50 miles; rise from the Hudson to the summit, in Sullivan county, 535 feet; thence to Carpenter's Point is a descent of 80; thence to the crossing of the Delaware, a rise of 148; and thence to Honesdale, a rise of 187 feet; total lockage 950; Honesdale 870 feet above tide water. The canal is 4 feet deep, and varies in width from 32 to 36 feet; 107 locks, each 76 by 9 feet.

Tanner, <u>A Description of the Canals</u>, p. 58.

APPENDIX B

Extract from a report of R. F. Lord, Esq., dated January 6th, 1847.

The original plan upon which the canal was constructed afforded 4 feet depth of water, and a maximum capacity for boats carrying cargoes of [illegible] tons.

The lowest rate of freight for which boatmen had been obtained in the coal business up to the year 1843, was $1.34 per ton; and it is not probable, that for any considerable increase of business, they could have been retained at that rate: for at that they were more or less transient, and frequently abandoned their boats.

In the month of September, 1842, a plan was adopted for enlarging the canal, to be accomplished by raising the height and increasing the strength of its banks and appendages, with materials taken mainly from its bed and berm side, below the surface of the usual boating head, sufficient to sustain 5 feet depth of water, improve its channel, and make it competent for boats to navigate it, carrying 40 ton cargoes, with a view of making a more desirable business for boatmen, and thereby reduce the rate of freight.

The improvement was commenced in the fall of 1842, and was prosecuted to considerable extent the ensuing winter, in order to realize in part its benefits for the year 1843, and to have it completed during the season of 184[illegible].

The depth of water was gradually increased during the season of navigation, as the banks were prepared to sustain it. Its immediate effects were apparent, from the boats which were adapted to the former head of 4 feet, being able to carry [illegible] increased cargo, in proportion to the additional depth of water. The best class of these boats had their sides raised in order to

improve the offered advantages; and new boats were built on an enlarged plan, to correspond with the improve[illegible]

At the close of the year 1841, a review of the improvement exhibited the following results:

There [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	$8,400
Do.	do.	do.	do.	184[illegible]	61,22[illegible]
Do.	do.	do.	do.	1841,	38,810
Making the amount up to the close of the year 18[illegible] equal to					$108,[illegible]

For the business of the year 1843, the boats commenced the season laden with cargoes the same as they carried in 1842; and although they [illegible] with greater facility in consequence of the improvement, and were able to carry cargoes of [illegible] tons before the close of the season, the average cargoes of all the boats, taken for the whole season does not clearly exhibit the advantages derived that year from the enlargement. The [illegible] cargoes for all the boats during the whole season, were $34\frac{18}{20}$ tons, and the average freight on the whole business of the year was $1.03 per ton; being a reduction of 31 cents per ton on 227,605 tons of coal, (the quantity in 1843,) and equal to the sum of. . . . . $70,55[illegible]

For the year 1844, the old pattern boats averaged $36\frac{11}{20}$ tons, those of the [illegible] that had been [illegible] $29\frac{4}{20}$ tons; and the new boats built for the enlargement, averaged $42\frac{13}{20}$ tons. All the boats taken together for the whole season averaged $40\frac{15}{20}$ tons per cargo, or trip; and the average rate of freight [illegible] cents per ton being a reduction from the rate in 184[illegible] of [illegible] cents per ton on 251,06[illegible] tons of coal, (the quantity in 1844,) equal to the sum of. 92,87[illegible]
showing the reduction of freight for 1843 and 1844, to have been. . . . . 163,4[illegible]

Deduct the amount expended for enlargement up to close of 1844.............................. 108,438.87

we have an excess in favor of enlargement equal to.. $51,990.53

After a review of the advantages derived from the enlargement of canal up to the close of the year 1844, it was resolved to continue the improvement on the same plan, and increase the depth of water to $5\frac{1}{2}$ feet, making the canal competent to the navigation of boats laden with 50 tons; and the requisite work has been progressing during the years 1845 and 1846, being now nearly completed.

There was expended during the year 1845, to complete the first contemplated enlargement, and to continue the improvement in view of increasing the capacity of canal up to the transit of boats laden with 50 tons, the sum of........................ 65,314.93

There has been expended during the year 1846, in continuation of the enlargement, including about $26,000 in raising guard banks, &c., to afford greater protection against extraordinary floods, the sum of.. 79,610.00

Making the aggregate amount for enlargement in 1845 and 1846,.................................... 144,924.93

In the year 1845 there was an extensive drought, which deranged the navigation more or less during 53 days; and during that period, the boats were laden with light cargoes, and an advance of freight made to compensate the boatmen. In consequence of this, the average tonnage [illegible] of boats for this year does not exhibit so fully the advantages of the enlargement, compared with the season of 1844. The new boats built for the enlarged canal, during the time there was a full supply of water in it, averaged $45\frac{11}{20}$ tons, and all the boats for the whole

[illegible] average 142 tons: the average rate of freight including the premium paid for the whole season was [illegible] 1842 [illegible] per ton [illegible] quantity [illegible] ... 93,446.65

[illegible]

[illegible] of [illegible] the season [illegible] was [illegible] per ton [illegible] per ton [illegible] paid in 1842 [illegible] 1840 [illegible] ... 158,116.00

[illegible] 1845 and 1846 ... $274,562.64

[illegible] amount expended for [illegible] during the years 1845 and 1846 ... $144,924.68

[illegible] 1845 and 1846 ... [illegible],637.11

Add [illegible] balance at the end of 1844 ... [illegible]4,991.58

Balance [illegible] at the end of 1846 ... $114,625.39

For [illegible] of the [illegible] past [illegible] which [illegible] per ton [illegible] equal to [illegible] 102 [illegible] ... [illegible]1,000.00

[illegible] 2,580 [illegible] ... 516,400.00

[illegible] ... [illegible],600.00

[illegible]

boats now, with 50 tons, is no greater than it was in 1842 with 30 tons. The annual repairs of boats have been reduced more than 33 per cent. by the improvement; and, although the rate of freight has been gradually reduced, the boatmen are more permanent, and [illegible]

During the years 1845 and 1846 a considerable proportion of the boats were of the old pattern, and adapted only to the first proposed enlargement, being competent to carry only 40 to [illegible] while [illegible] enlarged boats carried 48 to 50 tons; consequently, the average freight for those two years, does not exhibit so clearly the advantages of the improvement as it did for the two years of 1843 and 1844, when the boats were more competent to improve the increased facilities. The old pattern boats are being paid for, and their number considerably reduced every season, and their places supplied with boats built to correspond with the enlargement. Nearly all the old pattern boats will be withdrawn from the coal business during the years 1847 and 1848; after which the rate of freight can be brought down to correspond with the enlargement and increased facilities of navigation.

In 1842. 30 tons	at \$1.34	paid the boatmen	\$40.20 p. trip
50 "	84 cents	will pay them	42.00 " "

The results of the improvement on the canal will be,

1st. Increased strength [illegible] to resist the action of floods.

2d. Additional facilities and certainty of navigation on it.

3d. A large increase of its permanent capacity.

4th. A permanent reduction of about 50 cents per ton on the rate of freight.

All of which has been obtained without interrupting the regular navigation and [illegible]

Annual Report of the Delaware and Hudson Canal Company, 1846, pp. 11-16.

APPENDIX C

Problems with Raftsmen at the Delaware River Dam: 1829

. . . The Delaware River was originally 700 feet in width, and the building of the dam was given out by contract in the year 1828, for $1.00 per foot lineal measure. It was to be constructed 7 feet in height, and was finished and accepted by the company in the fall of 1829. In the spring of 1830 it was almost impossible for a raft to pass without being more or less wrecked. Meetings were organized by the lumbermen and resolution passed to remove the obstruction.

At the appointed time over 100 hardy pioneers of the forest with several teams, made their appearance, and the work of destruction commenced. Heavy blasts of powder were exploded, axes and saws were freely used, but when night threw her dark mantle upon the scene but little had been accomplished. For some unaccountable reason, the party packed their tools in the morning and departed for their several homes. The managers of the company immediately sent large gangs of men to repairing and fixing a place in the dam where rafts might pass in comparative safety, but their efforts were in vain, and it continued to be a terror to the river-men.

As a last resort the company employed a number of skillful water-men, paying them $10 per day, to navigate rafts through the perilous waters, and also paying damage to the owner of the lumber if any occurred in the passage. These men boarded the rafts at the mouth of the Lackawaxen river and were taken off in small boats below the dam. This expensive system was carried on for several years.

In the meantime the company was not idle. Repairmen were constantly at work building cribs, carting stone, brush and gravel, and acres of mountain forest including rocks and stones enough to build a second Chinese wall, have been thrown into the bed of the stream; and in addition to this hundreds of thousands of feet of hemlock timber and a few hundred tons of iron cost the company a mint of money, but today little if any danger is experienced by raftsmen in passing through the shute on the Pennsylvania side of the river. All damages paid to lumbermen perhaps cannot be strictly told, . . . but without this vast outlay of money, the Delaware and Hudson Canal Company could never have existed, and the canal would have been a failure. (WAYNE COUNTY HERALD, November 22, 1877, from the MILFORD HERALD)

Excerpted in Sanderson, Delaware & Hudson Canalway, pp. 30-31.

The Wire Suspension Aqueduct over the Allegheny River at Pittsburg.

The work recently constructed under this superintendence of John A. Roebling, the designer and contractor, has supplied the place of the old wooden structure, which originally was built by the state of Pennsylvania, at the western termination of the Pennsylvania canal.

The council of the city of Pittsburg, by whom, in consequence of an arrangement with the state, the tolls on this aqueduct are of late received, and who are bound to keep the work in repair, decided on rebuilding, and after considering various plans, adopted that of Mr. Roebling, and entered into contract with him, to reconstruct the communication for the gross sum, including the removal of the old ponderous structure and the repair of the piers and abutments, of \$62,000, a very small sum indeed for a work of such magnitude. As this work is the first of the kind ever attempted, its construction speaks well for the enterprize of the city of Pittsburg.

The removal of the old work, was commenced in September, 1844, and boats were passed through the new aqueduct in May 1845. This work consists of 7 spans of 160 feet each, from centre to centre of pier; the trunk is of wood, and 1140 feet long, 14 feet at bottom, 16½ feet on top, the sides 8½ feet deep. These as well as the bottom, are composed of a *double* course of 2½ inch white pine plank, laid dioganally, the two courses crossing each other at right angles, so as to form a solid lattice work of great strength and stiffness, sufficient to bear its own weight, and to resist the effects of the most violent storms. The bottom of the trunk rests upon transverse beams, arranged in pairs of 4 feet apart; between these, the posts which support the sides of the trunk, are let in with dovetailed tenons, secured by bolts. The outside posts which support the side walk and towe path, incline outwards, and are connected with the beams in a similar manner.—Each trunk post is held by 2 braces, 2½×10 inches, and connected with the outside posts by a double joist of 2½×10 inches. The trunk posts are 7 inches square on top, and 7×14 at the heel; the transverse beams are 27 feet long and 16×6 inches, the space between two adjoining is 4 inches. It will be observed, that all parts of the framing are double with the exception of the posts, so as to admit of the suspension rods; each pair of beams is on each side of the trunk, supported by a double suspension rod of 1¼ inch round iron, bent in the shape of a stirrup, and mounted on a small cast iron saddle, which rests on the cable; these saddles are on top of the cable, connected by links, which

diminish in size from the pier towards the centre. The sides of the trunk rest solid against the bodies of masonry, which are erected on each pier and abutment as bases, for the pyramids which support the cables.—These pyramids which are constructed of three blocks of a durable hard sand stone, rise 5 feet above the level of the sidewalk and tow path, and measure 3 · 5 feet on top, and 4 · 6½ feet at base. The sidewalk and towpath being 7 feet wide, leave 3 feet space for the passage of the pyramids. The ample width of the tow and footpath is therefore contracted on every pier, but this arrangement proves no inconvenience, and was necessary for the suspension next to the trunk.

The caps which cover the saddles and cables on the pyramids, are suspended next to the trunk, one on each side, each of these two cables is exactly 7 inches in diameter, perfectly solid and compact, and constructed in one piece from shore to shore, 1175 feet long; it is composed of 1900 wires of ⅛ inch thickness, which are laid parallel to each other, great care has been taken to insure an equal tension of the wires. Oxidation is guarded against by a varnish, applied to each wire separately, their preservation however is insured for certain by a close compact and continuous wrapping, made of annealed wire, and laid on by machinery in the most perfect manner. A continuous wrapping is an important improvement, which in this case has for the first time been successfully applied.

A well constructed and well wrapped cable presents the appearance of a solid cylinder, which in strength greatly surpasses a chain, made of bars of the same aggregate section or weight. It is not only the great relative strength of wire, which renders it superior to bar iron, but its greater elasticity, which enables it to support strong and repeated vibrations, add still more to its value as a material for bridge building.

The extremities of the cables do not extend *below* ground, but connect with anchor chains, which in a curved line pass through large masses of masonry, the last links occupying a vertical position. The bars composing these chains, average 1½×4 inches, and are from 4 to 12 feet long, they are manufactured of boiler scrap, and forged in one piece without a weld. The extreme links are anchored to heavy cast iron plates of 6 feet square, which are held down by the foundations, upon which the weight of 700 perches of masonry rest. The stability of this part of the structure is fully insured, as the resistance of the anchorage is twice as great as the greatest strain, to which the chains can ever be subjected.

The plan of anchorage adopted on the aqueduct, varies materially from those methods usually applied to suspension bridges, where an open channel is formed under ground for the passage of the chains. On the aqueduct, the chains below ground are imbedded and completely surrounded by cement. In the construction of the masonry, this material as well as lime mortar, have been abundantly applied. The bars are painted with red lead; their preservation is rendered certain by the known quality of calcareous cements, to prevent oxidation. If moisture should find its way to the chains, it will be saturated with lime, and add another calcareous coating to the iron. This portion of the work has been executed with scrupulous care, so as to render it unnecessary on the part of those, who exercise a surveillance over the structure, to examine it. The repainting of the cables every two or three years will insure their duration for a long period.

Where the cables rest on the saddles, their size is increased at two points by introducing short wires, and thus forming swells, which fit into corresponding recesses of the casting. Between these swells the cable is forcibly pressed down by three set of strong iron wedges, driven through openings, which are cast in the sides of the saddle.

When the merits of the suspension plan were discussed previous to the commencement of the structure, doubts were raised as to the stability of the pyramids and the masonry below, when unequal forces should happen to disturb the equilibrium of adjoining spans. It was then proved by a statical demonstration, that any of the arches with the water in the trunk could support an extra weight of 120 tons, without disturbance to any part of the work. In this examination no allowance at all was made for the great resistance of the woodwork and the stiffness of the trunk itself. During the raising of the frame work the several arches were repeatedly subjected to very considerable unequal forces, which never disturbed the balance and proved the correctness of previous calculations.

The stiffness and rigidity of the structure is so great, that no doubt is entertained, that each of the several arches would sustain *itself*, in case the woodwork of the next one adjoining should be consumed by fire. The woodwork in any of the arches separately may be removed and substituted by new material, without effecting the equilibrium of the next one.

The original idea, upon which the plan has been perfected, was to form a *wooden trunk*, strong enough to support its own weight, and stiff enough for an aqueduct or bridge, and to combine this structure with wire cables of a sufficient strength to bear safely the great weight of water.

The plan of this work therefore is a combination, which presents very superior advantages, viz. *great strength*, *stiffness*, *safety*, *durability* and *economy*.

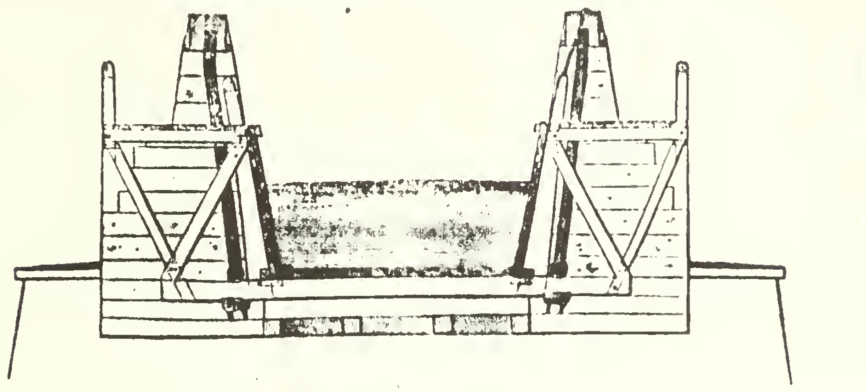
This system for the first time successfully carried out on the Pittsburg aqueduct, may hereafter be applied with the happiest results to railroad bridges, which have to resist the powerful weight and great vibrations which result from the passage of heavy locomotives and trains of cars.

REMARK.—The quantities in the following table are calculated for a depth of water of 4 feet, which has been in the aqueduct ever since the opening. The depth contemplated, was 3½ feet, a greater depth is at present required, on account of the raising of the bottom of the canal by bars and sediment which have to be removed before the level can be lowered.

TABLE OF QUANTITIES ON AQUEDUCT.

Length of aqueduct without extensions	1,140 feet.
" cables	1,175 "
" cables and chains	1,[illegible] "
Diameter of cables	7 inches.
Aggregate weight of both cables	110 tons.
Areal section of 4 ft. of water in trunk.	60 feet.
Total weight of water in aqueduct	2,100 tons.
" " one span	200 tons.
Weight of one span including all	400 tons.
Aggte. number of wires in both cables.	3,800
Aggregate solid wire section of both cables in superficial inches	53 inches.
Aggte. solid section of anchor chains.	72 inches.
Deflection of cables	11 ft. 6 inches.
Elevation of pyramids above piers	16 ft. 6 inches.
Weight of water in one span *between* piers	275 tons.
Tension of cables resulting from this weight	[illegible] tons.
Tension of a single wire " "	[illegible] lbs.
Average ultimate strength of one wire	1,100 lbs.
Ultimate strength of cables	2,090 tons.
Tension resulting from weight of water upon one solid square inch of wire cable	11,800 lbs.
Tension resulting from weight of water upon one sq. inch of anchor chains	11,000 lbs.
Pressure resulting from weight of water upon a pyramid	137½ tons.
Pressure resulting from weight of water upon one superficial foot of pyramid	18,400 lbs.

Section of the Suspension Aqueduct at Pittsburg, Pa.



"The Wire Suspension Aqueduct over the Allegheny River at Pittsburg," American Railroad Journal, XVIII (October 9, 1845), 648-49.

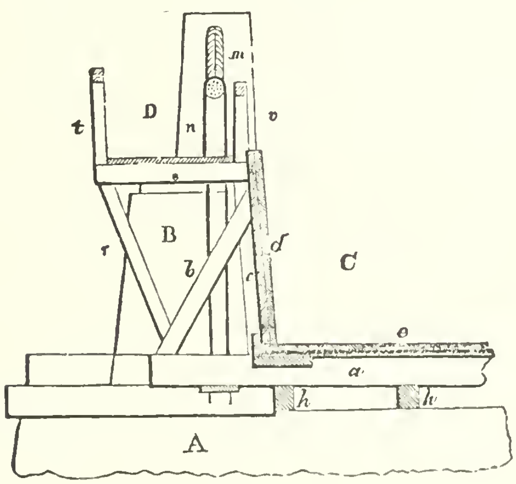


Fig. 148—shows in elevation a portion of the stone supports, and a cross section of the trunk, &c., of the Alleghany canal aqueduct-bridge.
A, piers.
B, Supports of masonry on the piers for the wire cables.
C, interior of a portion of the trunk.
a, cross-joists suspended from the cables *m* by the bent suspending-bars *n*, on which the bottom *e* of trunk rests.
b, inclined struts in pairs connected with the pieces *c* to support the sides *d* of the trunk.
D, tow-path.
s, cross-joists of the tow-path.
r, inclined supports of *s*.
t and *v*, parapets.
h, sleepers on top of the piers on which the cross-joists *a* rest.

Mahan, An Elementary Course of Civil Engineering, p. 273.

APPENDIX E

"Wire Suspension Bridge over the Monongahela, at Pittsburg."

The new suspension bridge over the Mongahela river at Pittsburgh, was commenced in June, 1845, and opened for travel in February, 1846. The piers and abutments of the old wooden structure, which was destroyed by the great fire, required extensive repairs to be fitted for the reception of the new superstructure. The whole length of the work between the abutments is exactly 1500 feet, and is divided in eight spans of 188 feet average distance from centre to centre. The piers are 50 feet long at bottom 36 feet high, and 11 feet wide on top, battering 1 inch to the foot.

Two bodies of substantial cut stone masonry, measuring 9 feet square and 3 feet high, are erected on each pier, at a distance of 18 feet apart. On these the bed plates are laid down for the support of the *cast iron towers*, to which the *wire cables* are suspended by means of *pendulums*. Each span being supported by two separate cables, there are, therefore, 18 cables supended to 18 towers.

The towers are composed of four colums, moulded in the form of a two-sided, or cornered, pilaster; they are connected by four lattice pannels, secured by screw bolts. The pannels up and down stream close the whole side of a tower, but those in the direction of the bridge form an open doorway, which serves for the continuation of side-walks from one span to the other.

On top of the pilasters or columns, a massive casting rests, which supports the *pendulum* to which the cables are attached. The upper pin of the pendulum lies in a seat which is formed by the sides and ribs of a square box occupying the centre of the casting. For the purpose of throwing the whole pressure upon the four columns underneath, 12 segments of arches butt against the centre box and rest with the other end upon the four corners.

The pendulums are composed of four solid bar of 2 feet 6 inches long, from centre to centre of pin, 4 inches by one inch—the pins are 3 inches in diameter. To the lower pin, the cable of one span is attached directly, and the connection formed with the next cable by means of four links of 3 feet 6 inches long and 4 inches by 1¼ inch.

The opposite cables, as well as the pendulums, are inclined towards each other—the distance between being 27 feet at the top of the towers, and 22 feet at the centre of a span. The pendulums on the abutments, however, occupy a vertical position.

The two sidewalks are outside of the cables, and 5 feet wide. The roadway between is contracted to 20 feet, and separated from the sidewalks by fender rails, which are raised from the floor by means of blocks of 6 inches high, 8 feet apart. The total width of the bridge between the railings, is 32 feet.

The anchor chains which hold the cables of the first and last span, are secured below ground in the same method which was applied to the aqueduct—their oxidation is guarded against in the same manner.

The cables are 4½ inches in diameter, and protected by a solid wrapping; they are assisted by stays, made of 1¼ inch round charcoal iron; the suspenders are of the same material, 1¼ inch diameter, and placed 4 feet apart.

The peculiar construction of the Monongahela bridge was planned with the view of obtaining a high degree of stiffness, which is a great desideratum in all suspension bridges: this object has been fully attained. The wind has no effect on this structure, and the vibrations produced by two heavy coal teams, weighing 7 tons each and closely following each other, are no greater than is generally observed on wooden arch and truss bridges of the same span. This bridge is principally used for heavy hauling; a large portion of the coal consumed in the city of Pittsburgh passes over it in four and six horse teams.

As a heavy load passes over a span, the adjoining pendulums, when closely observed, can be noticed to move correspondingly—the extent of this motion not exceeding one half inch. By this accommodation of the pendulums, all *jarring* of the cast iron towers is effectually avoided. Another object of the pendulums is to direct the *resultant* of any forces to which he work may be subjected, through the centre of the towers, as well as of the masonry below.

Two of the piers of the old structure had once given way in consequence of the shaking and pressure of the arch timbers, when subjected to heavy loads. Such an accident can never take place on the new structure, as the piers are only subjected to the quiet and vertical pressure of the towers.

I do not recommend the application of pendulums in all cases; but in this, it appeared to me the best plan which could be adopted.

The two towers on each pier are connected by a wooden beam, properly encased and lined by the same mouldings which ornament the top of the castings.

The lightness and graceful appearance of this structure is somewhat impaired by the heavy proportions of these connections, but I had to resort to it from motives of economy.

The whole expense of this structure does not exceed $55,000—a very small sum indeed for such an extensive work.

A great portion of this work had to be done during last winter, and in cold weather; it was accomplished without any accident, with the exception of one of the workmen who was seized by fits and killed by falling off a pier.

TABLE OF QUANTITIES OF MONONGAHELA BRIDGE.

Length of bridge between abutments	1500	feet.
Number of spans	8	
Average width of spans from centre to centre	188	feet.
Diameter of cables	4½	in.
Number of wires in each	750	
Weight of superstructure of one span, as far as supported by the cables	70	tons
Tension of cables resulting from it	122	"
Weight of four six-horse teams, loaded with 104 bushels of coal each	28	"
Tension resulting from it when at rest	49	"
Weight of 100 head of cattle at 800 lbs	40	"
Tension resulting from it when at rest	70	"
Aggregate weight of one span as far as supported by the cables, plus 100 cattle at rest	110	"
Tension resulting from it	192	"
Ultimate strength of two cables	860	"
Section of anchor chains	36	in.
Section of pendulums	62	"

"All the materials of iron used in the construction of the Monongahela bridge, as well as of the aqueduct, were manufactured at Pittsburg. The wire was furnished by Messrs. R. Townsend & Co. and by Mr. S. M. Wickersham."

"Wire Suspension Bridge Over the Monongahela, at Pittsburg," American Railroad Journal, XIX (June 13, 1846), 376-77.

"Mem of Charges to Delaware Aqueduct"

1846						
May	12	Paid	H Nelson for sledges		32	25
	14	"	Blecker & Oothout for Iron		36	34
	18	"	Wetmore & Co	drills	36	50
June	11	"	do	Iron	56	54
	"	"	do	Spikes	27	55
	24	"	at Rondout	Rope &c	32	10
July		"	do	Powder &c	114	
Sept	4	"	Wetmore & Co —	Spikes Iron & Steel	320	65
	5	"	Taylor	Blocks	35	
	22	"	at Rondout	100 Kegs powder	225	
Oct	25	"	Expenditures as p	R.F.L. Statmt. rend.	7.361	58
	27	"	H. Nelson	for hammers	13	50
	28	"	at Rondout	100 Kegs Powder	225	
Nov	7	"	Wetmore & Co	Iron	294	49
	23	"	do	"	59	53
	25	"	do	Forge	33	25
Dec	31	"	Expenditure as p	R. F. Leeds a/c Dec 31	(14.877	95
Jany	1	"	at Rondout	by Col Hendricks	52	50
	7	"	G. Watson		99	1
April	29	"	at Rondout	135 Kegs Powder	303	75
May	3	"	Expenditure as p	R.F.L. a/c	6.619	12
"	5	"	Wetmore & Co	Iron	1120	75
	31	"	do	"	161	74

June	5	"	Brennan J & Co	Rail Road Iron	201	38
	30	"	Wetmore & Co	Iron	28	75
	"	"	at Rondout	by Col Hendricks	4	
July	31	"	do	do	353	10
Aug	7	"	Wetmore & Co	Iron	152	36
	24	"	do	do	200	98
	31	"	at Rondout	freight goods	20	
Sept	21	"	Wetmore & Co	Iron	25	75
Oct	13	"	Expdrs acp R. F. Lord a/c ending July 31/47		13.835	18
					46.260	10
1847				brt forw	46.260	10
Oct	22	Paid	Bush & Co	50 bbls Pork	712	50
	23	"	Herrick & V B	150 " Flour	1.014	38
		"	O L & A. Ferris	10 " Mackerel	72	50
Nov	1	"	Wetmore & Co	Iron	635	11
	4	"	O L & A. Ferris	20 half bbl Mackerel	83	50
	9	"	Expend acp R. F. Lord a/c qr ending Sept 30		17426	57
	12	"	Mr. A. Roebling		6.000	
	30	"	at Rondout	by Col Hendricks	13	50
Dec	21	"	Laflin & Smith	450 Kegs Powder	1012	50
1848	31	"	at Rondout	freight of Powder	3	
Jany	4	"	Tucker Cooper & Co	Rope &c	605	28
	28	"	Expditure acp R. F. Lord a/c for qr ending Dec 31		20.652	.1
Feb	24	"	H. N. Peek	Duck	126	69
April	22	"	S. Judd's Sons & Co	Bill Oil	666	72
May	1	"	Wetmore & Co	Iron	150	60
June	23	"	do	Steel &c	35	97
	30	"	at Rondout	100 Kegs Powder	237	50
August	10	"	Expend acp R. F. Lord a/c qr ending June 31		10.367	74
Oct	19	"	do	do do Sept 30	10.913	20

"Statement of Acct. of Delaware Aqueduct," Lord Collection, Minisink Valley Historical Society.

Nov.	16	"	do do do Mch 31/48 having been omitted to be chgd at the proper time	8317	2
1849 Jan	5	For	Amts Paid to Mr. A. Roebling at sundry times by Mr Lord as per his Statement Jany 1/49	48161	16
	17	"	Amt Expended in construction as per Mr Lords a/c Vouchers to Dec 1	8957	77
				182425	34
	Less		Amt Chgd on 22 & 23d Oct & 14 Nov. for Flour Pork & Fish — Mr Lord having Charged himself with the same in his acct	1882	88
			Total as per Ledger	180542	46

APPENDIX G

Estimate for Neversink Aqueduct: October 25, 1848

4,600	lb Anchor Chains & Pins	10 cts	4,460	
35,200	" Castings	4 "	1,408	
10,150	" Wrought iron; Susp. &	7 "	700	50
37	Casks Spikes 3700 lb 4½ cts	5 "	185	
70,000	lb No 9 Wire in Cables	10 "	7,000	
3,500	" 14 Wrapping Wire	14 "	490	
2	Wrapping machines		100	
84,000	ft B. M. Oak timber for Anchorage	$15.00	1,260	
1,600	" " for Trunk	20.00	32	
59,000	" " Whitepine timber for Trunk	18.00	1,062	
60,000	" " Whitepine plank "	18.00	1,080	
30,000	" " Hemlock for Extensions	10.00	300	
292 ft	Caulking 1.00 $292 incl. Materials		300	
	Tarring & painting		100	
	Laying down Anchorage		300	
150,000	ft of timber & plank to frame & put up incl. all exp. (This includes extension, but no anchorage.)		2,000	
	Freight & extras		500	
		$	21,277	
			3,623	
		$	24,900	

"Never Sink Aquaduct. High Falls. Oct. 1848. . . ," Roebling Collection, Box 4, Rutgers, The State University.

APPENDIX H

Estimate for High Falls Aqueduct: October 25, 1848

39,300	lb	Anchor Chains & Pins	10 cs	3,930	
34,200	"	Castings	4 "	1,368	
12,000	"	Wrought-iron, Suspenders, Tension rods	7 "	840	
33		Casks Spikes 3300 lb	5 "	265	
44,000	lb	No 9 Wire in Cables	10 "	4,400	
2600	"	No 14 Wrapping Wire	14 "	364	
1500	Feet	Oak timber for Trunk	$20.	30	
46,200	"	White pine timber "	18.	831	60
52,000	"	White pine plank "	18.	936	
30,000	"	Hemlock for Extensions	10.	300	
~~260~~					
262	ft	Caulking & pitching	1.00	300	
		Tarring & painting		100	
		Putting down Anchorplates & Chains		100	
129,700		ft of timber & Plank to frame & put up incl all expenses. $13.00 pr 1000		1,686	
		Extras, ~~Freight~~, ~~Hauling~~ &		500	
		~~Freight on timber~~ &		~~500~~	
				$15,850	
				4,550	
				$20,400	

Box 4, Rutgers, The State University.

AMERICAN MANUFACTURE OF WIRE ROPES FOR INCLINED PLANES, STANDING RIGGING, MINES, TILLERS, ETC. BY JOHN A. ROEBLING, CIVIL ENGINEER.

The art of manufacturing ropes of *wire* is comparatively new. Numerous attempts have been made in Europe and here, and most of them have proved failures. A collection of parallel wires, bound together by wrappings in the manner of a suspension cable, is no rope and not fit for running, it can only be used for a stationary purpose. The first rigging made in England, was of this description. The difficulty in the formation of wire rope arises from the unyielding nature of the material; iron fibres cannot be twisted like hemp, cotton or wollen; their texture would be injured by the attempt. To remove this obstacle, some manufacturers have resorted to *annealing*, and thereby destroyed the most valuable properties of iron wire, viz. its great strength and elasticity.

My first attempts in the manufacture of wire rope; were made four years ago, my intimacy with the construction of wire cable bridges induced me to investigate this matter. The principles of my process differ from those of the English manufacturers, they are original and secured by patent. The novelty of my proceeding chiefly consists in the spiral laying of the wires around a common axis *without twisting the fibres*, and secondly in subjecting the individual wires while thus laying to a uniform and forcible tension under all circumstances. By this method, the greatest strength is obtained by the least amount of material, and at the same time a high degree of pliability. Each individual wire occupies exactly the same position

NOTE.—By the term elasticity, I mean the property of wire to stretch and give when subjected to a strain, and to resume its former length after the strain ceases, without suffering a permanent elongation. The extent of elongation of iron is in proportion to the tension. In estimating the strength of a rope, the strain it has to support, should never exceed the limit of elasticity. A permanent strain requires some more allowance.

The elongation of good wire of No. 14, 15 or 16, amounts, according to my own experiments to $\frac{1}{1000}$ of its length per ton per square inch. A strain of 15 tons upon a rope of 1 square inch section and 1600 feet long will produce an elongation of 2 feet. The limit of elasticity for working rope I have assumed at 18 to 20 tons per square inch, according to the size and quality of the wire. A greater strain will produce permanent elongation; and if repeated, at last a rupture.

throughout the length of a strand; another result of the precision and force applied in laying, is the close contact of the wires, which renders the admission of air and moisture impossible.

Three years ago I offered to the board of canal commissioners which was then in power in Pennsylvania, to put a wire rope of my manufacture on one of the planes of the Allegheny Portage railroad, at my own risk and expense, the value of the rope to be paid in proportion, as it rendered services equivalent to a hemp rope. This liberal offer however was rejected and not considered until the present board came into office. Last year I put three ropes, measuring in the aggregate 3400 feet, 4½ inches circumference, in operation on plane No. 3. Owing to the want of adhesion, I had at the start to contend with some difficulties. By means of a double groove on the receiving sheave and a guide sheave placed back of it, which crosses the rope and leads it from one groove to the other, which improvements were added to the machinery last winter; I succeeded in doubling the adhesion. When in unfavorable weather there is delay and slipping on the other planes the wire rope can at all times pull as heavy a load *without* a balance, as the engine is capable of hauling. The planes of the Portage railroad require hemp ropes of 8½ inches circumference, made of the best Russia or Italian hemp, and which cannot be trusted longer with safety than one season. They are frequently from reasons of economy continued 1½ seasons; much however, depends upon the weather and business. The unfavorable circumstances under which the wire rope had to work last year, effected it some; the wear of the whole of this season, however, is not perceptible, and its present condition promises a long duration. I am now manufacturing another wire rope of 5100 feet long in four pieces for plane No. 10.

The first rope of my make, 600 feet long, 3¼ inches circumference has now been in successful operation two seasons, hauling section boats from the basin to the railroad at Johnstown. Two more were put to work last spring at the new slips at Hallidaysburg and Columbia. From my present experience, I may safely assert that *wire rope* deserves the preference over *hemp rope* in all situations much exposed, and where great strength and durability is required.

By my process of manufacture, the same pliability is inparted to the rope which is proper to the wire itself. Paradox as this may appear, it is nevertheless a fact and is easily explained. By pliability is here understood the extent of flexure to which the rope or wire may be subjected, without producing a permanent bend; when released the rope must resume its former and straight position. To bend a rope requires force, and this force is in proportion to its areal section, *caeteris paribus*.

Well manufactured *iron rope* is *more* pliable than *hemp rope* of the same strength. I am manufacturing tillers of fine wire, capable of bearing 3000 lbs. and which ply around cylinders as small as four inches in diameter, and in which the wires are so compactly laid, that not the slightest shifting in their spiral position is to be observed. A number of my tillers are in use

on the Ohio and Mississippi. Such rope would be pliable enough for running rigging and be of long duration.

I will here add a few remarks on the introduction of *standing wire rigging* in place of *hemp rigging*. This subject has for some years passed, engaged the attention of the navy department of England and France, and the success which has attended the use of wire in place of hemp for shrouds and stays in the naval and commercial service of Great Britain, would, it appears, seem to warrant an attempt to test its utility on our national vessels.

Allow me to cite here a few remarks from the notes of Capt. Basil Hall, on a tour through Switzerland, and while examining the wire suspension bridge at Fryburg. He says, "attempts are now making and will ere long succeed, to introduce wire rigging, which is stronger and better than *chain*, because less dependent on the accidental quality and careless manufacture of a single part. How strange it is, that the plan of making *wire bridges*, so successfully adopted in France, and elsewhere, should not have found favor enough in England to be fairly tried on a large scale. Fryburg bridge 301 feet *wider* than Menai, at least equally strong, has cost only one-fifth of the money. I do not think wire will answer for running rope; but for standing rigging it may, I conceive, be most usefully substituted for hemp, for with equal strength experience shows it to be lighter."

The cables of suspension bridges are stationary and will, when protected against oxidation, last an indefinite period. Standing rigging, (when compared to running rope) is nearly stationary, and there is little wear but what arises from the direct strain, which if supported by sufficient strength, will have no deteriorating effect. In comparing the two materials, wire and hemp for rigging, the state of preservation and time of use should be considered. For instance, a hemp stay of a certain size, made of the best Italian hemp, will when new, possess two-thirds of the strength of a wire stay of the same weight per foot; but let the two stays have been exposed and served five years, then the strength of the hemp stay will be gone, while the wire stay will not show any perceptible reduction. In this case, of course, a common wear and tear is supposed.

The most prominent features of wire rigging as compared to hemp rigging, are its great durability, less weight and size, less surface exposed to wind, less danger in time of action of being destroyed by shot. Another good quality of the wire rope is its great elasticity which is quite sufficient to counteract the effect of a sudden jerk, while a vessel is rolling heavily at sea. The elasticity of hemp rigging is only to be relied on to a very small extent, it will give and stretch a great deal but not return.

A common objection of those not familiar with the nature of wire rope, is its supposed rapid destruction by oxidation, but no apprehension is less founded than this. Running wire rope while in use either in or out of water, in mines or any other situation, will not even require the protection of oil, varnish or tar; while at work it will rust no more than a rail or a chain in use, but when idle, oxidation will affect it in proportion to the surface expo-

sed. As, however, the process of laying is carried on with mathematical precision, by which the wires are brought into the closest contact, the assemblage of wires in form of a strand, present a solid rod, which will be no more subjected to rusting than the link of a chain of the same size. The individual wires as well as the strands and ropes are coated with an excellent varnish during the manufacture. Wire rigging will require no other protection but oiling or tarring once or twice a season. Where elegance is an object, black or green paint may be used. Rigging made of zinked wires and not painted, would present a most elegant appearance and be exempt from all rusting.

Wire rope can be spliced in the same manner as hemp rope. The attachment of wire shrouds to the sides of the vessel and to the masthead and their connection with the rattlines (which should also be of wire) can be effected by the old method; the use of wire however, will suggest some modifications better adapted to the material.

Some wire rigging has been manufactured in England which simply consists of a collection of parallel wires bound together and served over with hemp. These mixtures, as experience has proved in the case of tiller-ropes, are objectionable, the wire will rust inside of the hemp in spite of all protection by varnish; besides the cover of hemp, which adds nothing to the strength, is only an additional expense.

Iron is now gradually superseding wood in the construction of vessels, a complete revolution in ship building has already commenced in England. Although very expensive at first, iron ships will prove the cheapest in the end. Are there any well founded objections to wire rigging, which assumes the same relation to hemp rigging as wooden ships to iron ones? There are none. Why then not test this matter by encouraging those who are capable of bringing it to perfection? A number of iron vessels are now building for the naval and revenue service, which seem to offer appropriate occasions for the test of this matter.

Saxenburg, Pa., Sept. 1843.

American Railroad Journal, XVI (November, 1843), 321-24.

PATENT WIRE ROPE of JOHN A. ROEBLING,

Civil Engineer, Trenton, N. J.

		9	10	11	12	13	14	15	16	17
Wire Rope of Equivalent Strength of 49 Wires.	Price in Cents. Per foot.	31.87	28.27	23.31	19.68	15.50	11.70	10.26	8.54	6.00
	Price in Cents. Per pound.	11		11½	12	12½	13	13½	14	15
	Lbs. weight per foot.	3.17	2.57	2.03	1.61	1.21	0.90	0.76	0.61	0.40
	Circumference of Rope in inches.	4.66	4.20	3.50	3.25	3.00	2.80	2.25	2.00	1.55
Diameter of Iron Bolt	Of equivalent strength in inches	1 5/16	1 3/16	1 1/16	15/16	13/16	11/16	10/16	9/16	8/16
Hemp Rope.	Ultimate strength in Tons.	41	33½	26½	21	16	12	10	8	5
	Lbs. weight per foot.	5.70	4.60	3.65	2.95	2.23	1.63	1.37	1.10	0.73
	Circumference of Rope in inches.	11½	10¼	9½	8¼	7¼	6¼	5¾	5¼	4

		9	10	11	12	13	14	15	16
Wire Rope of Equivalent Strength of 133 Wires.	Price in Cents. Per foot.	86.13	69.85	64.74	55.20	43.75	31.20	27.00	22.10
	Price in Cents. Per pound.	11		11½	12	12½	13	13½	14
	Lbs. weight per foot.	7.83	6.35	5.63	4.60	3.50	2.40	2.00	1.60
	Circumference of Rope in inches.	7.00	6.25	6.00	5.25	4.25	4.00	3.50	3.13
Bolt.	Of equivalent strength in inches	2⅛	1⅞	1¾	1⅝	1 7/16	1 3/16	1 1/16	15/16
Hemp Rope.	Ultimate strength in Tons.	102	82½	73	60	45½	31	26	21
	Lbs. weight per foot.	14.07	11.43	10.13	8.28	6.30	4.32	3.60	2.88
	Circumference of Rope in inches.	17⅞	16¼	15¼	14	12¼	10	9¼	8¼

REMARKS.

When substituting Wire Rope for Hemp Rope, it is good economy to allow for the former the same weight, which experience has approved of for the latter, per foot run or per yard.

As a general rule, Wire Ropes will last from two to three times as long as Hemp Ropes.

To guard against rust, stationary ropes should be oiled with Linseed Oil, or painted with Red Lead, Spanish Brown, or any other durable paint, or they should be tarred from time to time. Running Rope, when in use, requires no protection. Wire Ropes will run on the same sized sheaves as Hemp Ropes of equal strength, but the greater the diameter the less the wear.

The adhesion of Wire Ropes is the same as that of Hemp Ropes. When giving orders, the diameter of sheaves, kind of machinery, and duty to perform, should be described. The size of wire and rate of twist will be determined accordingly. Wire Ropes should not be coiled or uncoiled like Hemp Ropes, but should be reeled, so as not to affect the twist. The manufactured rope is reeled upon a drum, which, when mounted upon a wooden spindle, between two supports, and made to revolve, will pay off the rope in the same manner in which it received it.

Wire Ropes are substituted for Hemp Ropes and Chains, on Inclined Planes, for Standing Rigging on board of Sailing Vessels and Steamers, Ferry Ropes, in Mines, for all kinds of heavy hoisting, with or without blocks and tackles, in Foundries, for stays on derricks, Cranes and Shears, for staying Chimneys and Masts, for Tillers, Towlines, Lightning Conductors, for Suspension and other Bridges, Crossing Rivers for Telegraph uses, &c. &c.

TERMS CASH.

Roebling Collection, Box 4, Rutgers, The State University.

SOME REMARKS ON SUSPENSION BRIDGES, AND ON THE COMPARATIVE MERITS OF CABLE AND CHAIN BRIDGES.—*By J. A. Roebling, Civil Engineer. No.* 1.

The subject of suspension bridges is beginning to engage the attention of the profession. To cause public opinion to incline in favor of this species of structure, can only be accomplished by the successful erection of some good specimens. The ocular demonstration they will offer, will advance this cause more than all treatises. Among the profession, however, this matter cannot be too much discussed, provided the discussion is carried on by men who are familiar with the features of the system.

The writer takes this occasion to remark that he has, ever since the introduction of suspension bridges upon the continent, made himself intimate with the system, that he had some excellent opportunities of becoming practically acquainted with the details of construction, and that he has, with devoted interest, taken notice of all the improvements which have gradually been introduced.

Chain bridges originated in their improved form in England, and were, in the course of a few years, introduced into France and Germany. The material of which the chains in most of these bridges are manufactured, is common iron. The bars, composing the links, are generally about 15 feet long, 4 inches deep, and three-fourths of an inch thick, therefore presenting a sectional area of 3 square inches.

The difficulty of insuring the iron in such dimensions of an uniform and even quality and strength throughout, is obvious, and hence the large quantity of iron expended in chains to insure strength and safety. The general practice has been to allow from 16 to 20,000 lbs. per square inch, as the maximum strain to which chains should be subjected in the most trying case. This is rather less than one-third of the actual strength of iron bars. A far greater allowance of strength is made for the suspension rods, which are more liable to be seriously affected than the chains. Experience and fatal accidents which have occurred to some carefully planned and executed suspension bridges have proved that the usual allowance of strength for the chains and rods is not by any means too ample. With the exception of some accidents which were the results of defects in the bars, and which only prove that the latter had not been sufficiently examined and tested, it can be shown that the most serious injuries to which suspension bridges may be subjected, can be guarded against more successfully by some alterations in the system, and by resorting to some simple expedients, than by a mere increase of strength in the chains.

On the occasion of the erection of several suspension bridges over the arms of the Danube, in the city of Vienna, a body of scientific Engineers undertook a series of experiments on the strength of different sorts of iron, steel and wire. The actual capacity of iron to sustain a powerful strain uninjured, does not so much consist in its ultimate tenacity as in its elasticity. A bar of good iron

may sustain a strain which approaches the limits of its strength without breaking, but a succession of such trials, which are beyond its elastic capacity, will gradually stretch it permanently, and cause at last a rupture.

Any strain upon a bar of iron, no matter how trifling, will produce an actual elongation of its fibres. Owing to the elastic quality of iron, the fibres will contract again as soon as the cause of the strain is removed. But this will only take place to a certain extent. The extent of the elongation to which the fibres may be subjected without having their power of contracting at all impaired, is the limit of elasticity on which we can safely rely. Therefore, iron should never be strained beyond this limit. This rate of elasticity in common bar iron amounts to about one third of its ultimate strength. If, therefore, thirty tons are required to break a bar of iron of one square inch, the strain it can support without injury, will amount to ten tons. If this strain is frequently repeated, and applied for a considerable length of time, it should be reduced to eight tons or even less.

The result of the experiments at Vienna was, that the Engineers decided in favor of steel as the material to be used for the chains; the elastic power of this metal, and the greater uniformity of its grain, being so much superior to that of iron, that greater strength and safety could be obtained for less expense by using it instead of iron. It is proper to remark here that the steel used in these bridges was manufactured of natural steel ore, and cost but little more than iron.

Note.—Natural steel ore is found in abundance in Austria, and in the famous mining districts of Seigerland, in Prussia. A few remarks on the Muessener mountain in the latter district may not be uninteresting to those who intend to visit the continent and the river Rhine, from whence they can easily reach the celebrated steel mine at Muessen. The steel ore has no resemblance to common iron ore, and looks more like crystalize feldspar than any thing else. The mine at Muessen where this ore is found in its greatest purity, has been worked since time immemorial, and it is computed, that when the ore is exhausted, the mere pillars, which are now left to support the roofs, will furnish a supply for many centuries more.

This mine is not worked in the common way, and has a remarkable appearance. The visiter descends a broad flight of steps, arched over at a convenient height to walk upright. Arr'ved, at the floor of the gallery, he finds himself at the entrance o a magnificient hall and succession of halls, with dome shaped ceilings supported by pillars. These excavations have been made in the solid ore, and the effect of the reflection of the light, when properly illvminated, from the millions of crystals of ore composing the walls, all around, is very beautiful and fairy-like. This sight is worth a trip of 100 miles to enjoy.

The South American market, and part of the West India market is largely supplied with all sorts of implements and cutlery, made of this natural steel ore.

[It may be well to remark that a similar ore is not uncommon in the United States. [Ed. R. R. J.]

Since these steel suspension bridges were constructed, wire cables in place of chains were more generally introduced by the French Engineers, and gradually prevailed over the whole continent.

The superiority of wire cables over chains cannot be contested for one moment, why the English Engineers still cling to the old system, after they have seen the principle of wire cables successfully tested, and particularly after they have witnessed the success of the Friburg bridge, which exceeds the Vienna bridge in boldness. Why, after so much experience, they do not abandon the use of chains, is to me truly a matter of astonishment.

The ultimate strength of wire as used in cable bridges, is two-thirds greater than that of iron bars as used for chains. The proportion of elasticity to the ultimate strength is greater in wire than in iron. 52,000 lbs. may be relied on with safety, as the extent of the elasticity of wire per square inch.

On the other hand, iron is much cheaper in the form of bars of several square inches section, than in the form of wires of $\frac{1}{8}$ inch thick. But the manufacture of wire cables is a great deal simpler and cheaper than the manufacture of chains. The cost of a wire cable bridge will generally be found less than of a chain bridge of the same strength. But there are some peculiar features belonging to the cable system which should decide in its favor even at an advance of cost.

The process of wire drawing, imparts to the iron a great uniformity of grain. If a strand is made of good iron, and sound at its ends, it is generally good throughout. Unsound places are mostly visible on the surface. The toughness of wire strands is easily examined by testing the two ends. The actual test of all the strands throughout can likewise easily be effected.

A cable is constituted of a great number of wires. Admitting now that a few unsound strands, in spite of all care and vigilance,

should find their way into a cable, their number would be too small to affect the strength of the whole materially. All the single wires are coated with a durable varnish, and the finished cable is coated again, and may be effectually protected against the influences of the weather by a tight wrapping throughout. The wrapping has also the advantage of preventing the unequal expansion and contraction of the inner and outer wires, when exposed to the rays of the sun, and sudden changes of temperature. Cables can in this manner be more effectually protected against oxidation, than chains of bar iron. The beauty of a well manufactured cable is, that all the component parts are uniformly placed and equally strong throughout. Each single strand bears exactly its portion, and thus the greatest strength is effected by the least amount of material.

The floor of a chain bridge is suspended by vertical iron bars; in cable bridges these suspenders are formed by small wire cables, which should always have an inclined position. Even where a chain bridge should be found preferable to a cable bridge, the suspenders should be invariably made of wire. Wire suspenders are pliable, and will easily move with the floor, when set in motion by the wind. The fastenings of the suspenders at the two ends cannot give away; but it has frequently occurred on chain bridges, that the heads of the suspension rods have been snapped off in consequence of the wrenching and twisting.

I will notice here the remarks of Colonel Pasley upon the effect of storms, communicated in the Transactions of the Institute of Civil Engineers:—

"By the hurricane of October 11, 1835, one-third part of the roadway of the Suspension Bridge at Montrose (410 feet span,) with a very small exception, was carried away. The suspension rods on the west side were either broken or very much bent, but the chains, 4 in number, and extending in two parallel lines, of two tiers each, appeared perfect. It is our opinion, based on observations, that the motions which a bridge experiences, are not *lateral*, but *longitudinal*. The Hammersmith suspension bridge does not appear to be subject to these longitudinal motions, even in a most violent gale, and this is amply accounted for by the longitudinal trussing which is there adopted. The idea, that these longitudinal motions, and the injuries to the road-ways of suspension bridges, are owing to the violent action of the wind from below, is confirmed by what Colonel Pasley witnessed in Nov. 1836, at the Chatham Dock Yard. One side of the roof of a shed for ship-building, was raised up and down repeatedly, until at last, a large portion of it, about 40 to 50 feet. was floated up like a sheet of

paper, and carried to a distance of 50 yards. Such being the violence of the wind, we may readily conceive that the continual extension and compression to which the suspension rods must be subject, by the rise and fall of the road-way, is prevented in the Hammersmith bridge, by four lines of strong trussing along the whole length of the road-way, firmly connected to the bearers below. No similar trussing exists in the Menai, the Montrose, or any other suspension bridges which Colonel Pasley has seen. The rise and fall of the platform of the Menai bridge is confidently stated to be three feet in ordinary gales, so that unless some similar trussing be employed, it may reasonably be expected that this bridge will be seriously injured in some future hurricane. The peculiar construction of the suspenders in several pieces, with joints, is a source of security to this bridge which the others do not possess. The author believes that no suspension bridge of 400 feet betwixt the piers can be considered secure without two inflexible lines of longitudinal trussings from pier to pier."

American Railroad Journal, XII (March 15, 1841), 161-66.

'SOME REMARKS ON SUSPENSION BRIDGES, AND ON THE COMPARATIVE MERITS OF CABLE AND CHAIN BRIDGES.—*By J. A. Roebling, Civil Engineer. No 2.*

Storms are unquestionably the greatest enemies of suspension bridges. As to the action of the wind, however, upon these structures, there appears to be a diversity of opinion among Engineers. I will offer some remarks which are the result of observation and reflection.

Those who have had an opportunity of examining chain bridges, will know that it requires comparatively but a small force to put the chains and the whole floor in an oscillating motion, as they are suspended vertically, and will follow the laws of the pendulum.

Railings and longitudinal vertical trusses will not prevent these oscillating motions, but a stiff and well-constructed floor will offer a great resistance.

The floors of almost all the English suspension bridges are entirely too light; better specimens in this respect are to be found on the Continent.

When the force which sets a pendulum in motion is continued to be applied at regular intervals, which correspond with the oscillations and their directions, the effect will be a great extension of these oscillations. The scope of oscillations of the heaviest weights thus suspended and operated upon, may be very much increased. Forest trees which have withstood the effects of storms for ages, have only escaped the fate of other less fortunate individuals, because the gusts of wind never happened to correspond with the oscillating motions of their tops. Chance saved them. It is the

[illegible] suspension bridge. When a [illegible] blows side-ways against the floor and [illegible] of a suspension bridge, an oscillating motion to a small extent will soon be produced. The irregular succession of gusts of wind, which but seldom will correspond with the oscillations of the bridge, will be the very means of stopping them; and thus many a bridge has withstood the fury of gales unhurt.

But suppose, while the bridge is oscillating to a great extent, another furious stream of air happens to strike it, just at the time it is moving in the same direction, the effect which then will be produced cannot fail to be destructive.

Thus, we see that a mere calculation of the effect of wind upon a body when suspended, will give a result far short of what actually may and has taken place.

Vertical currents of air may be, no doubt, as violent as horizontal currents; but the former will never do much harm to a well-constructed bridge.

The experience in suspension bridges was very limited at the time Mr. Telford displayed the power of his genius by the erection of the noble Menai. No provisions were made by him to secure the platform against the action of vertical currents, although the position of that bridge admits of the most effectual application of remedies which will never fail.

Mr. Brunel, jr., was the first who applied the proper means to guard against the effect of vertical currents, and to a certain extent also against side currents, in the construction of a suspension bridge on the Isle of Bourbon, where hurricanes are of frequent occurrence.—(*See Navier's Memoir sur les Ponts Suspendres.*) In this bridge the platform is held down by stages, fastened by the lower ends to reversely-curved chains, the ends of which are secured in the piers and abutments. Thus the platform is completely secured vertically. At the same time the ends of these reversed chains recede from the bridge horizontally, and act as diagonal stays in the latter direction.

The same expedient can be applied to the Menai bridge more effectually, as the floor is elevated nearly 100 feet above the water. This, together with strong cast iron parapets, and a better constructed floor, would no doubt insure the safety of this noble work for all ages to come.

Chains are suspended in vertical planes, and when put into a swinging motion, cease to offer a uniform support to the suspension rods.

Cables are, and should always be suspended in inclined, or rather

curved inclined planes; but this cannot be done with chains. Herein consists one of the main superiorities of cables over chains.

The planes, in which the cables are suspended, being inclined towards each other, give at once to the floor a horizontal stability, especially at the middle of the bridge, where it is most needed. It requires a wind of great force even to displace a platform thus suspended, to any extent, and regular oscillations are next to impossible.

This principle of inclining the cables may, in situations exposed to frequent storms, be carried out to a greater extent than it has been. It is necessary, however, in such cases, that the cables should be supported by towers, and not single unconnected columns, as they have a tendency to thrust the latter towards each other.

The Friburg bridge is suspended by four cables of $5\frac{1}{2}$ inches each in diameter. Two cables are placed on each side. There is, however, no practical difficulty in uniting any number of cables into one single cable, so that there may be but *one* cable on each side, to which all the suspenders on that side are attached. A single cable will be superior to a pair of cables when displaced by lateral forces. The arrangement of the cables in inclined planes is also rendered easier, when but one cable is formed, than when they are collected into pairs.

In order to increase the vertical stability of suspension bridges of a great span, it will be useful to bring the weight of the cables into action by connecting them with the floor at intervals, either by timbers or cast iron pipes, which may include the suspenders. The floor then cannot be raised at any place without lifting a considerable portion of the cables and of the whole bridge.

The greatest trial to which a suspension bridge may be subjected, next to storms, is the march of a body of soldiers, moving over it in regular file and step. A crowd of people, moving promiscuously, will not produce a strain so severe as the momentum of a much smaller body of men, the united weight of which is rising and falling at regular intervals. In the latter case, a regular vertical oscillation of the platform longitudinally will take place, and the momentum of the load will unite with the momentum of a great portion of the bridge, in producing shocks which greatly exceed the strain produced by a promiscuously moving load. Heavy railways and stiff connections between the floor and cables, and a stiff floor, will contribute much to counteract such effects.

Large bodies of troops, when moving over such bridges, should always be ordered out of step. Several accidents produced by the above cause are now on record.

The above remarks have not been made with a view of bringing suspension bridges into discredit. To impute such a motive to me would be unjust. No one can be a greater admirer of the system than myself. The superiority of these structures, and especially cable bridges, over all other kind of bridges, needs no argument of mine. Abler men have established this long ago.

In speaking of the weak points of the system, I have only intended to show how much caution is necessary in planning and executing a suspension bridge in order to insure perfect safety. It appears that the destruction of so many wooden bridges by the late freshets, would urge the adoption of a system which is beyond the reach of ice and floods. But, to insure the successful introduction of cable bridges into the United States, their erection, and especially the construction of the first specimen, should not be left to mere mechanics. No modern improvement has profited more by the aid of science than the system of suspension bridges. And we see that all the noble and bold structures of this kind which have been put up in Europe, were planned and executed under the immediate superintendence of the most eminent Engineers, whose practical judgment was aided by a rich store of scientific knowledge.

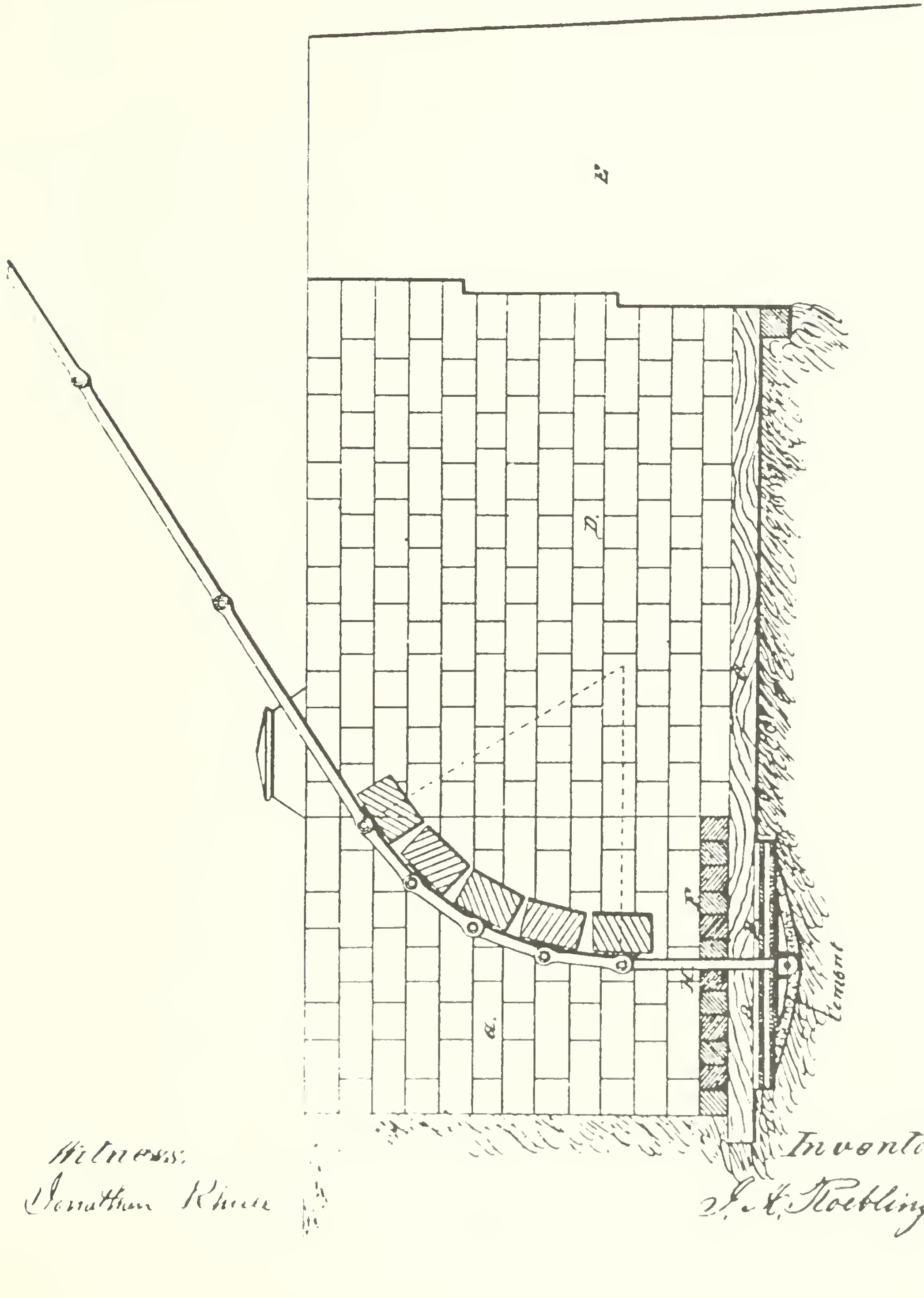
American Railroad Journal, XII (April 1, 1841), 193-96.

APPENDIX L

Patent No. 4710, August 26, 1846, Anchoring Suspension - Chains for Bridges

J. A. Roebling.
Suspension Bridge.

No. 4,710. Patented Aug. 26, 1846.



Witness:
Jonathan Rhue

Inventor.
J. A. Roebling

UNITED STATES PATENT OFFICE.

JNO. A. ROEBLING, OF PITTSBURGH, PENNSYLVANIA.

ANCHORING SUSPENSION-CHAINS FOR BRIDGES.

Specification of Letters Patent No. 4,710, dated August 26, 1846.

To all whom it may concern:

Be it known that I, JOHN A. ROEBLING, civil engineer, of Pittsburgh, Allegheny county, State of Pennsylvania, have invented a new plan of Constructing Wire-Cable or Chain Suspension-Bridges; and I do hereby declare that the following is a full and exact description.

My improvement consists in a new mode of anchorage, applicable to wire bridges as well as chain bridges.

My plan of anchorage differs very materially from the mode hitherto pursued. It is principally calculated for such locations, where there is no rock, and where an artificial anchorage has to be made. In most cases, the practice has been, to resist the pressure of the anchor plates, to which the chains or cables are attached, and which are continued below ground in a straight course, directly by a large mass of solid masonry, constructed either in the form of arches or straight walls, and butting against the abutments, upon which the towers rest, which support the chains or cables. In this case the pressure is transmitted to a small surface of stone wall, which has to be constructed with great care and of the best material to prevent the breaking of the anchor plate and the irregular settling of the masonry. And as the base of this masonry is but small, its extent in length must be proportionally large so as to offer the necessary resistance. In place of resting the anchor plate directly against a stone wall, I apply in my mode a system of timbers, which serve in a manner as a foundation for the superincumbent masonry, distribute the great pressure of the anchor plates over a large surface of masonry, reduce therefore its length or depth, and by its yielding and elastic nature prevent the breaking of the anchor plates. I prefer curving the chains or cables below ground in place of continuing them straight. It is also my practice, to surround all the iron below ground by hydraulic cement and wall it in with solid masonry, in place of leaving an open channel as is the case in most suspension bridges. The cement with which I surround the chains or cables preserves them against rusting effectually. Where greater precaution is deemed, the chains may be inclosed in lead.

The accompanying drawing shows a longitudinal section of the plan of anchorage, which has actually been applied by me to the new Monongahela bridge at Pittsburgh. A similar plan was applied to the suspension aqueduct, constructed by me. In both structures the suspension cables connect with anchor chains, made of solid bars. The last or extreme links occupy a vertical position, and every one of the short links rests upon a solid stone block, well bedded in the lower masonry. The bed plate to which the last link is attached, is marked in the drawing by the letter A, it is laid in a thick bed of hydraulic cement. At the end of a bridge, which is suspended to two cables or chains, there are two anchor plates laid opposite to each other. At the Monongahela bridge the distance between these plates is 27 feet from center to center. On top of each anchor plate a platform B is laid down, of about 10 feet square and 8 inches thick, composed of 4 courses of 2-inch white oak plank, the courses crossing each other at right angles, and all spiked together with iron spikes. A thin layer of cement is spread over the anchor plate before the plank is laid down. An opening is left in the center of the platform for the passage of the chain H. The platform being well settled down, leveled and covered with cement, a course of timbers C is laid down next which extends to the abutment E and is as wide as the platform B and composed of white oak sticks hewed 12 inches square and of an even thickness. The two courses C which are opposite each other, serve for the support of the resisting walls D which support the pressure of the curved chains, and also for the support of the main course of foundation timbers marked F. This course is composed of about 12 white oak sticks, 12 to 15 inches thick, 40 feet long and extending all the way across the pit. It serves for the support of the masonry G, the weight of which is to resist the pressure of the anchor plates. This body of masonry being about 40 feet long and 12 feet wide, need not be very deep to offer a sufficient resistance to the pressure of the anchor plates. All the timbers are copiously grouted with thin lime mortar for the purpose of preservation. They will never rot as they are deeply buried under ground and entirely excluded from the air. The success of the above plan of anchorage, which is entirely novel and original in all its features, has been demonstrated on the aqueduct and Monongahela bridge, lately constructed under my superintendence.

What I claim as my original invention and wish to secure by Letters Patent is—

The application of a timber foundation, in place of stone, in connection with anchor plates, to support the pressure of the anchor chains or cables against the anchor masonry of a suspension bridge—for the purpose of increasing the base of that masonry, to increase the surface exposed to pressure, and to substitute wood as an elastic material in place of stone, for the bedding of the anchor plates,—the timber foundation either to occupy an inclined position, where the anchor cables or chains are continued in a straight line below ground, or to be placed horizontally, when the anchor cables are curved, as exhibited in the accompanying drawing, the whole to be in substance and in its main features constructed as fully described above and exhibited in the drawing.

JOHN A. ROEBLING.

Witnesses:

JONATHAN RHULE,

ALEX. MILLAR.

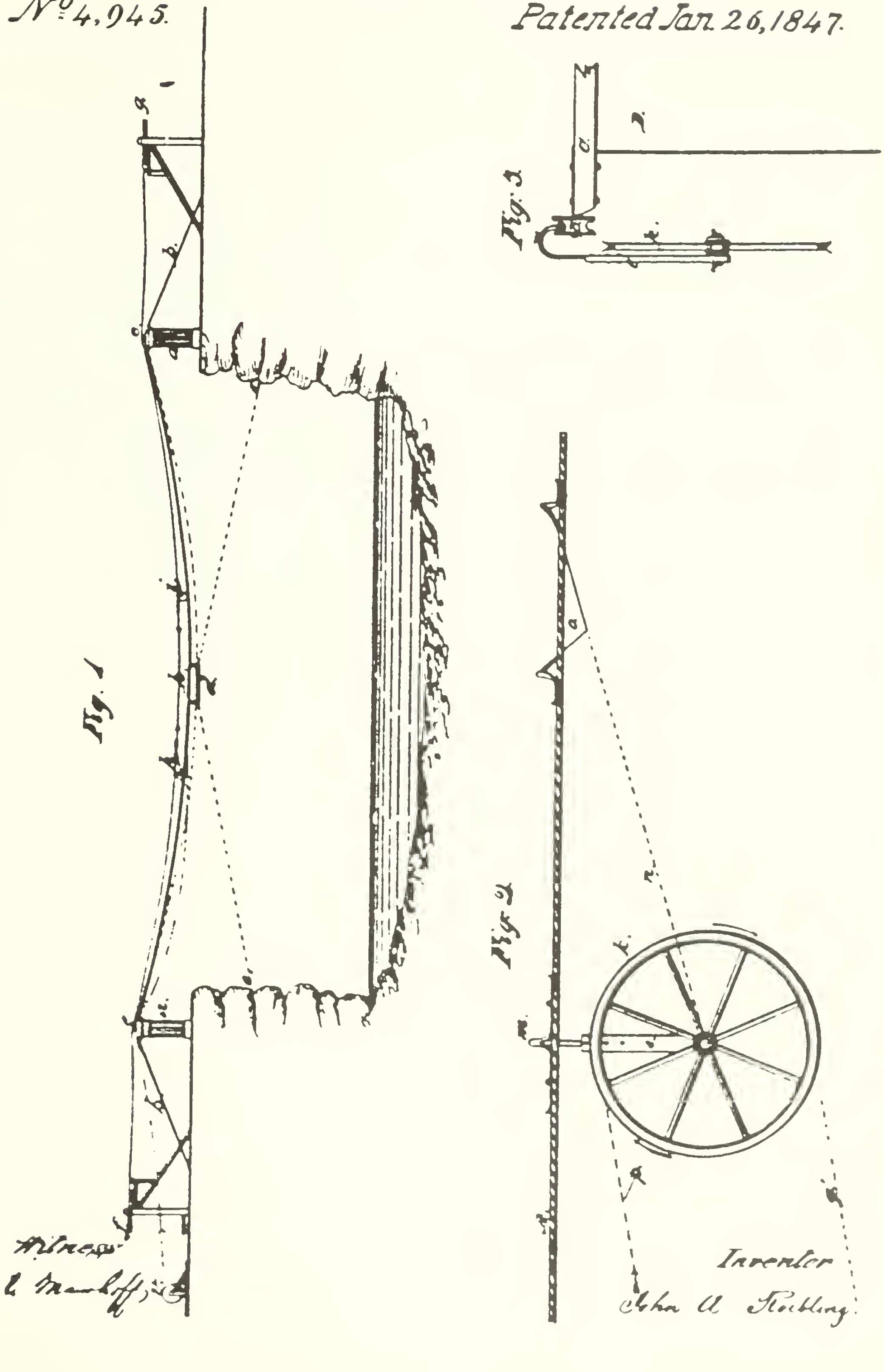
APPENDIX M

Patent No. 4945, January 26, 1847, Apparatus for Passing Suspension - Wires for Bridges Across Rivers, &c.

J. A. Roebling.
Suspension Bridge.

No. 4,945.

Patented Jan. 26, 1847.



4945

UNITED STATES PATENT OFFICE.

JNO. A. ROEBLING, OF PITTSBURGH, PENNSYLVANIA.

APPARATUS FOR PASSING SUSPENSION-WIRES FOR BRIDGES ACROSS RIVERS, &c.

Specification of Letters Patent No. 4,945, dated January 26, 1847.

To all whom it may concern:

Be it known that I, JOHN A. ROEBLING, civil engineer, of Pittsburgh, Allegheny county, State of Pennsylvania, have invented a new Method of Traversing Wires Across Rivers or Hollows for the Purpose of Forming Suspension-Cables for the Support of Bridges; and I do hereby declare that the following is a full and exact description.

For the sake of illustration, I have in the accompanying drawing presented a section of the Niagara River above the whirlpool, where a bridge is contemplated, and where my system of forming wire cables, may be applied to the best advantage.

a a represent the two towers for the support of the wire cables *b b b*, to which the floor is to be suspended; the cables are supposed to be in the course of construction.

c d c is a double wire rope, which is suspended across the chasm for the support of a small platform *d*, upon which those persons are stationed, whose business it is to regulate the tension of the wires. As there will always be two cables to be manufactured, opposite each other, this platform is to extend from one to the other; and in order to steady it horizontally, it is held by four wire stays, indicated by the dotted lines *d e d e*, which are anchored in the sides of the bluffs.

f is a horizontal wheel or sheave 16 to 20 feet in diameter, attached to a vertical shaft, which is to be turned by horsepower. This wheel has on its periphery a groove, for the reception of the endless rope *f c h i c g*. On the opposite bank of the river, a similar wheel, marked *g* is put up, around which the endless rope passes. In case the towers are built separately for the support of the cables, and not connected with each other, the endless rope may be worked between the towers. But where the towers are connected, as is supposed in the case before us, the endless rope has to be passed over the summit and outside of the towers, and should be supported on rollers, as is exhibited by Figure 3. This rope may be of hemp, but a wire rope, which will not stretch, is much preferable. Two traversing or traveling wheels, marked *h* and *i*, by which the wires are passed from shore to shore, are attached or suspended to the endless rope. The mode of construction of these wheels is represented in Figs. 2 and 3 on a larger scale.

A Fig. 2 exhibits a portion of the endless rope. A single rope might be substituted in place of the endless one and only one traveling wheel worked in place of two. A double or endless rope and two wheels are however much more expeditiously.

K represents a wheel of from 4 to 5 feet diameter, constructed of wood very light, its rim is furnished with a large groove made of sheet tin. It revolves freely around an accurately turned off spindle, which is attached to a vertical arm *l*, either made of wood or iron, and which terminates at its upper end in a neck, bent like a bow, and marked *m*, which is attached to the rope A by means of twine or wrapping wire. The object of the neck *m* is to clear the rollers B at the towers or upon piers, if there are any. Where there are piers, I put up on each a frame for the support of two rollers, to support and work the endless rope.

n indicates a pair of wires, which with one end are fastened to the ends of the spindle at the center of the wheel, with the other to the lower point of a small triangle O, made of inch pine board, and armed with two iron necks, bent like the neck *m*, for the purpose of cleaning the rollers B. The triangle with the wires *n* are to pull the wheel along and preserve its vertical position.

The operation of the whole apparatus is as follows: The skeins of wire, of which the cables are to be formed, are in the first instance united by splicing their ends, and reeled on large reels, capable of holding 1,500 pounds of wire or more. One of these reels is marked *v* in Fig. 1. It may further be mentioned, that a cable is usually formed of one single endless wire (which is composed of a great number of skeins, spliced) which is passed around a cast iron shoe or segment, at each end of the cable. When a cable is to be commenced, the end of a wire is fastened to the segment next to the reel, then passed around the groove of the traveling sheave; the horse is then started, which sets the endless rope in motion and causes the traveling sheave to advance. But as the one end of the wire is fast, the other must play off the reel and pass around the traveling sheave, which thus keeps on revolving until it reaches the opposite shore, where the machinery is stopped. A double wire has now been traversed from one shore to the other, it is then taken off the traveling sheave, by detaching one of the pulling

wires *n*, passed around the segment and adjusted. While this is accomplished, the two traveling sheavs on the other side receives a wire from another reel, and is started across the river, the first traveling sheave returning empty. The rope is therefore worked reciprocally and the horse reversed at the end of every trip.

Those persons, who are stationed on the suspended platform *d*, make their passage in a basket or box, suspended to the endless rope, the box being taken off, when wire is running. Or the basket may be suspended to a separate rope, which may be worked by a windlass.

The above mode of traversing wires, has in its main features been successfully applied in the formation of the cables of the suspension aqueduct at Pittsburgh, constructed by me.

What I claim as my original invention, and wish to secure by Letters Patent, is—

The application of traveling wheels, suspended and worked, either by a double endless rope, or by a single rope, across a river or valley, for the purpose of traversing the wires for the formation of wire cables, the whole to be in substance and in its main features, constructed and worked, as above described, and illustrated by the drawings.

JOHN A. ROEBLING.

Witnesses:

John E. Herbet,

Leonard S. John.

APPENDIX N

Description of Wire Cable Suspension Bridge Construction
By John A. Roebling, 1867

The art of cable making is of modern origin. The brothers Seguin, French Engineers, first undertook, in the early part of this century, to construct wire cables in the place of chains, for the suspension of bridge floors. A number of light structures were erected by them and others over the Rhone and other rivers of France. But owing to the light and frail character of these works, most of them have broken down or been destroyed by storms. M. Chaley, another distinguished French Engineer, at the end of the first quarter of this century, erected the suspension bridge at Freibourg over the valley of the Sarine in Switzerland. This work, as the largest span in Europe, measuring 870 feet between the towers, has for many years been an object of great engineering interest. But owing to the want of stiffness, and also of strength, its lifetime appears to be precarious.

By the practice of these engineers, a certain process for the construction of wire cables became established, and was considered the only method which would insure success, until by the erection of the Suspension Aqueduct over the Alleghany river at Pittsburgh, from 1844 to 1845, an opportunity was afforded to me to demonstrate on a large scale the practicability of another system, in all respects superior to the French. Previous to this undertaking, I had been engaged for years in experiments on wire ropes and cables. I had fully succeeded

in the introduction of this manufacture into this country, and my ropes were then in successful operation on the inclines of the old Alleghany Portage in Pennsylvania, since abandoned, and on other planes. I was therefore well prepared to engage in a work, which in its general plan, as well as in its execution, was considered by the profession in the light of a hazardous and unwarranted novelty. The success of that work, and of eight others, including the Niagara railway bridge, the Alleghany bridge, and the Cincinnati bridge, all constructed on my plans and under my personal direction, have fully established this new system of cable making.

The object of these remarks is to gratify the desire of some professional men, and to explain, what I have never done before, the difference between the French system and mine. The principal feature of the French plan is to suspend the floor to a number of small cables. By my plan only two large cables are suspended, one on each side. The Cincinnati bridge is supported by two large cables, $12\frac{1}{3}$ inches diameter. The cables in my bridges are always assisted by stays, and this feature is entirely wanting in the French system. The question now arises, what advantage is gained by one large cable over a number of small ones? The old saying, that united we stand, but divided we fall, applies literally to this case, but in a double sense. Suppose the tension of the different wires is uniformly the same in both arrangements, and suppose both systems are caused to oscillate by a heavy gale, then the group of small cables is subject to the danger of a variableness in their individual motions. While some of them move up, others may swing down, and perfectly uniform resistance is then rendered impossible. If the small separate cables are united into one, no such variableness can exist. No matter to what oscillations the large cable may be exposed, they are always met by its united strength. In the

divided system one cable may break after the other, because they cannot be expected to act in perfect unison. The correctness of this view was fully demonstrated by the catastrophy which overtook the Wheeling bridge on the 17th of May, 1854. This bridge forms a span of 1010 feet from center to center of tower, the length of the floor is 960 feet—its width was 24 feet, supported by 12 cables, 6 on each side, with an aggregate number of wires of 6,600 No. 10 guage. If the tension of the Wheeling cables had been as uniform as those of the Cincinnati bridge are, then their relative strength would have been as 7 to 12. No stays were employed in the Wheeling bridge. The floor was torn by the gale into three sections, the eastern portion measured 500 feet, the western 300 feet, leaving the central part 200 feet long. All the cables but two broke loose from the anchorage, *one after another*. One small cable, composed of 150 wires, broke in the center. For the want of stays and of stiffness, the floor was subjected to very considerable oscillations, and thus broken up and destroyed *by its own momentum*.

A divided system of cables possesses but a small degree of that inherent stiffness which is obtained by forming one single massive cable, bound up in a continuous wrapping of such strength that it approaches the stiffness of a solid cylinder. The great stiffness and rigidity of our cables was forcibly illustrated during the suspension of the beams. A temporary track was laid down over the center of the beams for the transportation of materials on trucks. The beams being free to swing, the remarkable stiffness of this track was in part owing to the great weight of the cables, but also in a great measure to their stiffness. After the center girders had been put in place and connected with the beams, the stability of the skeleton floor was so far increased that loads of 5 tons weight produced but little impression.

Another and most important advantage of large and heavy compact cables in large spans is obtained from their powerful *horizontal* action in bracing the center of the span. Only those who have tested this matter on a large scale are able to appreciate it. I do not expect professional men to credit the statement, without seeing with their own eyes, that the center of the Ohio bridge is not deflected by heavy gales, neither horizontally nor vertically. This remarkable horizontal stability is in a great measure due to the powerful bracing of the cables. This admirable feature of a well built cable bridge cannot be introduced into a chain suspension bridge, without involving details of great difficulty.

The French system was first introduced into this country during the construction of the Schuylkill river bridge, at Fairmount, Philadelphia, by the late and much lamented Col. Charles Ellet, jun., who, like a true hero, sacrificed his life in his successful endeavors to make steam rams efficient on our western waters during the late civil war. According to this system the small cables are made on shore, or away from the bridge, then dragged to the site and elevated to their final position. But this practice is very objectionable, because the wires composing a cable, when under no strain, become loose, bulged out, and in consequence dislocated and entangled more or less. This derangement is much increased by the great abuse the cables suffer during the process of dragging, hoisting and placing in position. No matter what care may have been taken to insure uniform tension, this uniformity will be lost by the subsequent rough handling. The hardness and elasticity of good cable wire will approach that of steel. But this elasticity may be the means of destroying the uniformity of tension if this tension is relaxed.

My earliest experiments taught me that the French system is wrong in principle, and that no good cable can be made by that process. This objection may in part be overcome by employing a continuous wrapping, but not altogether. Nor is there always sufficient room available on shore for the construction of long cables. What then is the remedy? The cables should be made across the river, very nearly in the position which they will finally occupy, and the tension of the wires must never be relaxed below a safe mark. This system, which I have applied for the last 23 years, with invariable success, is the only true one which will insure uniformity of tension. I admit that this system is apparently more complicated than the French; it requires more extensive machinery, also more judgment and supervision, but it is the only plan to make a good cable.

Reports on the Ohio Bridge, at Cincinnati . . . April 1, 1867, pp. 48-52.

APPENDIX O

Income Approach to Value of Delaware Aqueduct, 1969

Income:

Gross Receipts			\$17,625.

Expenses:

Fixed Expense:

Taxes	\$553.		
Insurance	303.		
Total Fixed Expense:		\$850.	

Operating Expenses:

Labor	\$5,850.		
Electric	1,070.		
Maintenance & Repair	2,284.		
Supplies	237.		
Total Operating Expense:		\$9,441.	
Total Expenses			\$10,297.
NET Income			7,328.
Capitalized @ .119052			61,569.
Rounded to			61,500.

Justification of Capitalization Rate

M = mortgage percentage
C = mortgage coefficient
Y = yield
R = overall rate
Assume mortgage of 75%, 15 years, 10½ % interest, investment period 10 years.

$R = Y - MC$
$R = .15 - .75\ (.041264)$
$R = .15 - .030948$
$R = .119052$

APPENDIX P

CONTRACT BID SCHEDULE [1980]

REPAIR WORK ON ROEBLING BRIDGE

UPPER DELAWARE NATIONAL SCENIC AND RECREATIONAL RIVER

(LIN. FT. = Linear Feet; L.S. = Lump Sum)
(S.Y. = Square Yard)

ITEM NO.	SPEC. REF.	EST. QUAN.	UNIT	ITEM WITH UNIT BID PRICE	UNIT PRICE	AMOUNT BID
1.	780	24	Each	Supply and replace floor beams, using new 6" x 14'-24' long treated timber beams installed, at per each,	$______	$______
2.	780	56	Each	Supply and replace sway braces, using new 4" x 8" - 6' long treated timber, installed, at per each,	$______	$______
3.	780	4	Each	Supply and replace sway braces, using new 4" x 8" - 4' long treated timbers, installed, at per each,	$______	$______
4.	780	---	Lump Sum	Remove all existing railing, decking and stringers of the two center spans of the bridge and salvage all reusable timbers as directed in field by the Contracting Officer or by his Representative at per lump sum,		$______
5.	780	---	Lump Sum	Remove all existing railing and decking of the two end spans of the bridge and salvage all reusable timbers, as directed in field by the Contracting Officer or by his Representative, at per lump sum,		$______

ITEM NO.	SPEC. REF.	EST. QUAN.	UNIT	ITEM WITH UNIT BID PRICE	UNIT PRICE	AMOUNT BID
6.	780	3	Each	Replace three (3) bent or missing suspender rods and support plates (to be supplied by the National Park Service, at per each,	$________	$__________
7.	780	60	Each	Supply and install new 4" x 8" - 14' long treated stringers in the two center spans, at per each,	$________	$__________
8.	780	24	Each	Supply and install new 4" x 8" - 16" long treated stringers in the two center spans, at per each,	$________	$__________
9.	780	156	Each	Supply and install new 4" x 8" - 18' long treated stringers in the two center spans, at per each,	$________	$__________
10.	780	742	Each	Supply and install new 3" x 8" - 10' long treated bridge decking in the two center spans, at per each,	$________	$__________
11.	780	990	Lin.Ft.	Supply all new treated timber and construct hand railing between piers and abutments along full length of bridge using 4" x 6" - 6" long rail posts and 2" x 10" rail planks including all 5/8" dia. galvanized steel bolts of the required lengths, nuts and washers complete in place, at per lin. ft.	$________	$__________
12.	780	990	Lin.Ft.	Supply all new material and construct curbing between piers and abutments along full length of bridge using 6" x 6" - 12' long treated timber with treated spacer and nailer blocks, including galvanized steel bolts, nuts & washers, at per. lin. foot,	$________	$__________

ITEM NO.	SPEC. REF.	EST. QUAN.	UNIT	ITEM WITH UNIT BID PRICE	UNIT PRICE	AMOUNT BID
13.	780	140	Each	Replace deteriorated 4" x 8" - 16' long stringers in the two end spans and increase the number of stringers to set spacing at 16" on center using salvaged stringers from the two center spans, at per each, ________	$________	$________
14.	780	245	Each	Replace deteriorated 3" x 10" - 10' long decking in the two end spans using salvaged decking from the two center spans, at per each,	$________	$________
15.	780	---	Lump Sum	Repair stone masonry abutment at the Pennsylvania side, at per Lump Sum,		$________

TOTAL A: (Items 1 through 15).............. $________________

SUMMARY FOR CONTRACT AWARD

GENERAL INFORMATION: Bidders are required to quote on all the above items in order for their bid to be considered. SPEC. REF. (Specification Reference) refers to the construction specification describing the work. In case of discrepancy between words and figures, the words shall govern. In case of error in the extension of prices, the unit price shall govern. In case of bidder's error in summation of totals the individual bid item amounts corrected and totaled shall govern. Failure to enter unit prices shall be cause for rejection of bid.

BASIS OF AWARD: Award of the contract is contingent upon the amount of available funds. The quantities (except "lump sum" items) shown above are estimated and will be used for the purpose of canvassing the bids. Award will be made to one bidder only, on the basis of the low bid, for the total of A as shown above. However, after award, the Contracting Officer will have the right to increase or decrease any or all of the estimated quantities by twenty-five (25%) percent or to increase or decrease any one or of the quantities by any amount provided that the total cost of the original contract (exclusive of "lump sum" items) is not changed by more than twenty-five (25%) percent. Payment to the Contractor will be made on the basis of the actual quantities of the work completed. The Contracting Officer reserves the right to reject any and all bids.

APPENDIX Q

Excerpts from
"Delaware and Hudson Canal Bridge . . . October 1982 . . .
A. G. Lichtenstein & Associates. . . ."

INSPECTION RESULTS

The bridge was inspected in April, 1982. The dimensions and conditions of each of the elements were established as follows:

1. Deck: Recently laid 2-1/2" x 10" oak plank floor consisting of approximately half new planks and half older planks in fair to poor condition.
2. Stringers: 2-3/4" x 7-1/2" oak timbers, a number of stringers were found to be in a deteriorated condition and will require replacement.
3. Floorbeams: The 6" x 14" timber floorbeams show major deterioration particularly in the area of hanger connections. The new floor made it difficult to establish with certainty the amount of deterioration in each and every stringer and floorbeam.
4. The timber railing posts and railing appear to be satisfactory.
5. Hangers: The 1-1/4" Ø steel rod hangers seem to be satisfactory. AGLAS received from the Park Service, one (1) original hanger for testing. This hanger had been damaged and previously replaced.
6. Cables: Each cable consists of seven (7) strands made up of approximately 307 wrought iron wires for a total of 2150 wires per cable. Mr. Frank Neeld, a cable specialist associated with AGLAS for this project, made two (2) field inspections and prepared a sketch for unravelling one sag area of one (1) of the cables where deterioration was evident. This work requires an experienced structural steel contractor and is estimated to cost between $10,000. and $15,000.

Another area of concern was the entrance of the cable into the saddles over each pier where deterioration was extensive, a flat area. The cast iron enclosure on top of the saddle was lifted and the cable inspected. A short strand of one of the cables was tested for material strength and chemical composition. Our visual inspection of the cable found numerous areas of unravelling and missing protective wrapping on the cable and some areas where rusting of the cable was evident. At the entrance of saddles some broken wires were noted on the outside of strands.

7. Anchorage: The seven (7) strands flare out at the anchorage and are connected to wrought iron eyebars which are embedded in the stone abutment/tie backs. The condition of the cable and eyebars were noted to be satisfactory.

8. Piers and Abutments: The piers and abutments are constructed of stone masonry. The upstream face of the piers are built out to protect against ice flow. Initially timbers were installed on the upstream face for added protection. Much of the masonry joints on the piers were found to require repointing and the stone nosing on the upstream face has undergone severe erosion.

ANALYSIS OF CABLE SYSTEM

A study of the configuration of the cable and the spans reveal that a computer program for this type of project is not easily adapted. We, therefore, decided to perform long hand calculations for the following Cable Loading conditions:

1) Unstiffened cable in tension (due to its own weight) and the bridge dead load as supported by it - with frictionless connections over the piers. Stiffness of the deck was assumed to be negligable.

2) A ten thousand pound load "was placed" in the middle of the span and a frictionless connection was assumed at each pier.

3) A ten thousand pound load "was placed" at the middle of span and full fixity was assumed at each pier.

The deflection caused by Condition 2 was calculated at 41". The deflection caused during Condition 3 was calculated to be approximately 13".

The stiffness of the timber deck, railing posts, and horizontal rails and other connection elements obviously affect the performance of the cables. This stiffness or ability of the roadway to distribute load over a larger number of hangers is difficult to determine. It appears that a stiffening truss will have to be considered under any circumstances of vehicle loading. We therefore suggested a loading experiment be performed by us with the assistance of the National Park Service in order to get a more accurate understanding of the behavior of the cable and roadway deck acting together.

LOAD TESTING

A load test of the structure was conducted by AGLAS on Thurday, August 19, 1982. Points on the existing cables at all four (4) spans were set and elevations were taken with no load on the Bridge by use of a level located on the embankment. A pre-weighted truck (9360 Lbs. truck with driver and timber planking totals approximately 5 tons) was moved onto the Bridge and placed along the center line of roadway with its centroid located above the center of the New York span. Elevations were taken at the pre-set points on the cable at all four spans. The truck was then moved to the center of each of the next 3 spans and elevations of the pre-set points on the cable taken. After the truck was removed from the Bridge on the Pennsylvania side, elevations were again taken with the Bridge unloaded. Barricades were unfastened on the Pennsylvania Approach to allow the truck to be removed without driving back across the Bridge.

Deflections in the range of 2" were measured at the center of each span when the truck was located at that span. Downward deflections of the cable of up to 3/4" were measured in adjacent spans. See the attached table of measured deflections.

The final unloaded reading indicated 3/4" to 1" deflection of the cable as compared to the initial unloaded readings. This could be caused by temperature change of more than 20^{o} from the initial readings in the morning and final reading in the afternoon. Measured deflections were adjusted to compensate for this temperature change in the calculations.

Analysis of the cable - deck system under the known load and deflections indicate that the Bridge has sufficient stiffness to spread the concentrated wheel loads to a uniform load distributed over approxima ly 40' to 60'. This additional stiffness significantly reduces deflections

from the idealized case considered under the original cable analysis. The deck does not however act as a full length stiffening member for the entire span but only provides local stiffness to the structure. Thus without additional stiffening, the span is subject to rippling and swaying which reduces the life of the cable and requires increased maintenance cost to the timber deck system. Cable tension for dead load and the 5 ton truck loading were calculated to be within 110 to 114 kips (1,000 Lbs) depending on actual span length, actual sag of each span and measured dimensions. See the following table:

SPAN	ADJUSTED MIDSPAN DEFLECTION	CABLE TENSION*	CABLE STRESS* ASSUMING 60% OF CABLE WORKING
1E	1 3/8"	113.4^k	4.85 ksi
2E	1 1/4"	111.9^k	4.78 ksi
3E	1 7/8"	109.8^k	4.69 ksi
4E	2 5/8"	110.8^k	4.74 ksi
1W	1 5/8"	113.5^k	4.85 ksi
2W	1 5/8"	112.2^k	4.79 ksi
3W	1 1/2"	109.5^k	4.68 ksi
4W	1 5/8"	110.3^k	4.71 ksi

Based on the stiffness of the deck, and the result of the test, it appears that approximately 60 to 80% of the cable strands are working.

* K = kips = 1,000 Lbs. KSI = kips per square inch

Because of the above findings we feel the bridge is capable of carrying vehicular traffic with the use of properly designed stiffening truss. The magnitude of deflections also indicate that if the bridge were to remain as a crossing for pedestrians only, no stiffening trusses are needed. However, the Park Service could still consider the inclusion of Cable unravelling under the Cable Protection work in conjunction with the final design of a vehicular crossing.

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PRIMARY SOURCES

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High Falls, New York. Delaware and Hudson Canal Historical Society. Wakefield Collection.

Milford, Pennsylvania. Pike County Courthouse. Recorder of Deeds. Land Records.

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Monticello, New York. Sullivan County Government Center. Recorder of Deeds. Land Records.

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Autograph Collection of Simon Gratz.

Wurts Family Papers (Collections A and B).

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Port Jervis, New York. Minisink Valley Historical Society. Russel F. Lord Collection.

Scranton, Pennsylvania. Edward H. Huber Collection (private).

Troy, New York. Rensselaer Polytechnic Institute. Richard Gelman Fixman Library. Roebling Collection.

Washington, D. C. National Archives. Records of the Patent Office, Record Group 241.

The two primary collections of Roebling manuscripts are those at Rutgers, The State University, and Rensselaer Polytechnic Institute. All drawings, plans, and manuscript materials relative to the Delaware Aqueduct in these two collections have been copied and will be submitted to the park library/archives at Upper Delaware National Scenic and Recreational River.

The materials in the Danny A. Stango and Edward H. Huber collections were helpful in chronicling the history of the aqueduct during Huber's ownership from 1942 to 1973.

The post-1898 chain-of-title of the aqueduct was determined by research in the Land Records at the Pike County Courthouse and the Sullivan County Government Center.

Considerable material relative to the Delaware Aqueduct, which has not been available to researchers until recently, was found in the Russel F. Lord Collection at the Minisink Valley Historical Society.

The various division and personal files at the Mid-Atlantic Regional Office provided documentation for the National Park Service efforts to acquire and stabilize/preserve the aqueduct.

Documents in Record Group 241 at the National Archives provide information on Roebling's patents in the field of suspension bridge engineering.

Photographs of the Delaware Aqueduct in the Delaware and Hudson Railway Corporation Records, the Danny A. Stango Collection, and the Wakefield Collection have been copied and will be submitted to the park library/archives at Upper Delaware National Scenic and Recreational River.

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Of these documents, the Annual Reports of the Delaware and Hudson Canal Company, the Delaware & Hudson Canal Co. against Penn. Coal Co., the Report of Messrs. Benj. Wright and J. L. Sullivan, and the Pleadings provided useful documentation relative to the construction and operation of the Delaware and Hudson Canal and the Delaware Aqueduct. The various reports and treatises by Roebling provided background for the study of his accomplishments and contributions to suspension bridge engineering. The two congressional documents provided data relative to Roebling's patents.

Maps

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Originals of the Weston maps were found at the headquarters of the Delaware and Hudson Railway Company in Albany, New York, while xerox copies of the microfilmed maps were found at the Ellenville Public Library

and Museum. It is recommended that the National Park Service give consideration to the acquisition of the originals.

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The newspapers provided considerable data on the Delaware Aqueduct for the period from the late 1960s to the present. Articles in the Milford Dispatch and The Wayne Independent were helpful in documenting the history of the structure during the immediate aftermath of its sale by the Delaware and Hudson Canal Company. The one article in The Hancock Herald was useful in documenting the date and extent of damage of the 1933 fire.

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reflections by Young, McLaughlin, Donnelly, Suydam, and Weber provided data as well as "local color" concerning the operation of the canal and aqueduct.

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Carl A. Draxler, Minisink Ford, New York, May 3, 1983.

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John Traver, Barryville, New York, May 5, 1983.

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George J. Fluhr, Pike County Historian, April 7, 1983.

Interview via Letter

Olive Brower Finenko, Chenango Forks, New York, May 12, 1983.

Of these interviews, the most useful and helpful for this report were those with Huber (1940s-70s), Draxler (1920s-present), the Haupts (1910s-present), Leona Davis (1950s-present), Orson Davis (1950s-present), and Finenko (1930s). It is recommended that an oral history program be initiated and that the aforementioned persons be interviewed on tape.

Persons Consulted

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and Wickersham. Biographical data and data on Roebling's career accomplishments are found in the articles in Transactions, American Society of Civil Engineers (1933) and Engineering (1867). The best contemporary descriptions of the Delaware Aqueduct after its completion are found in the American Railroad Journal (January 13 and July 7, 1849). Considerable information on Roebling's other Delaware and Hudson Canal aqueducts may be found in the articles by Booth and Boynton. The articles by Schuyler (Engineering and Contracting) and on the Haupts discuss the changes to the Delaware Aqueduct in 1930-31.

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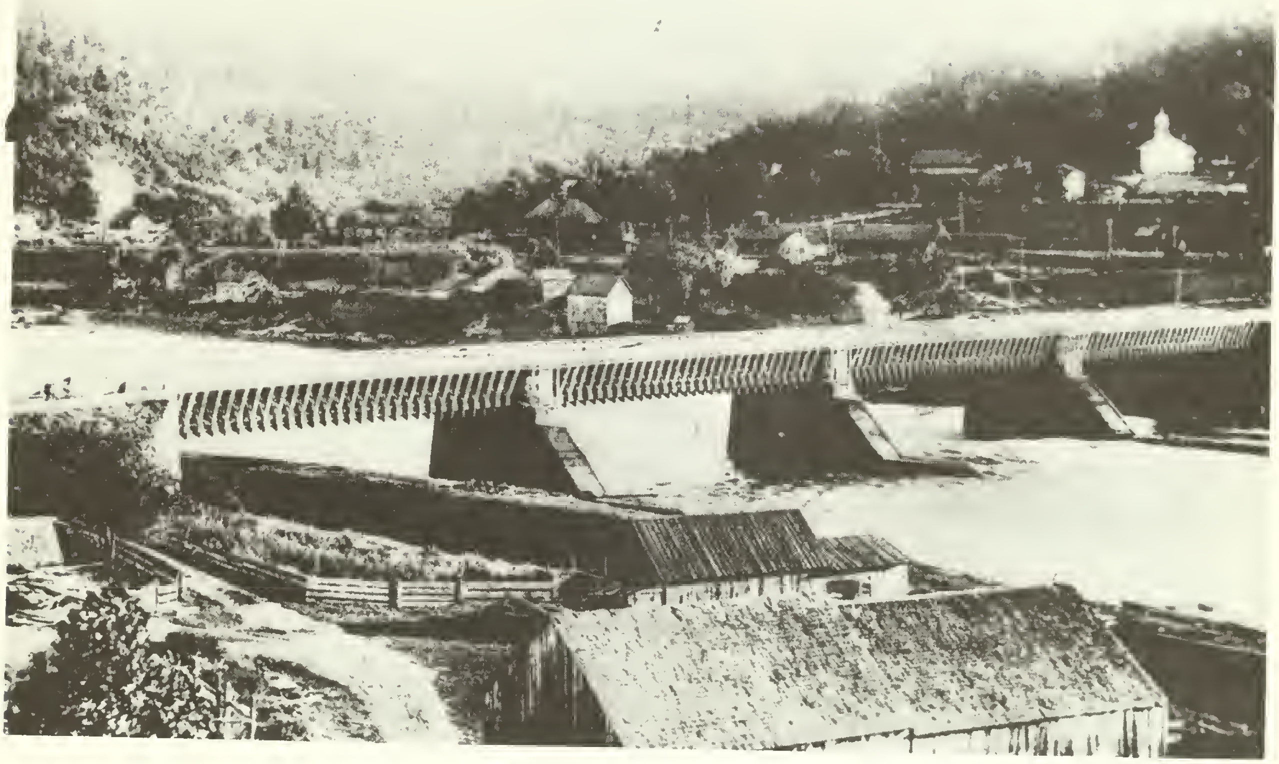
Of these studies the most useful for the history and present conditions of the Delaware Aqueduct were the "Appraisal," and the studies by A. G. Lichtenstein & Associates, the Historic American Engineering Record, McDermott, and Vogel.

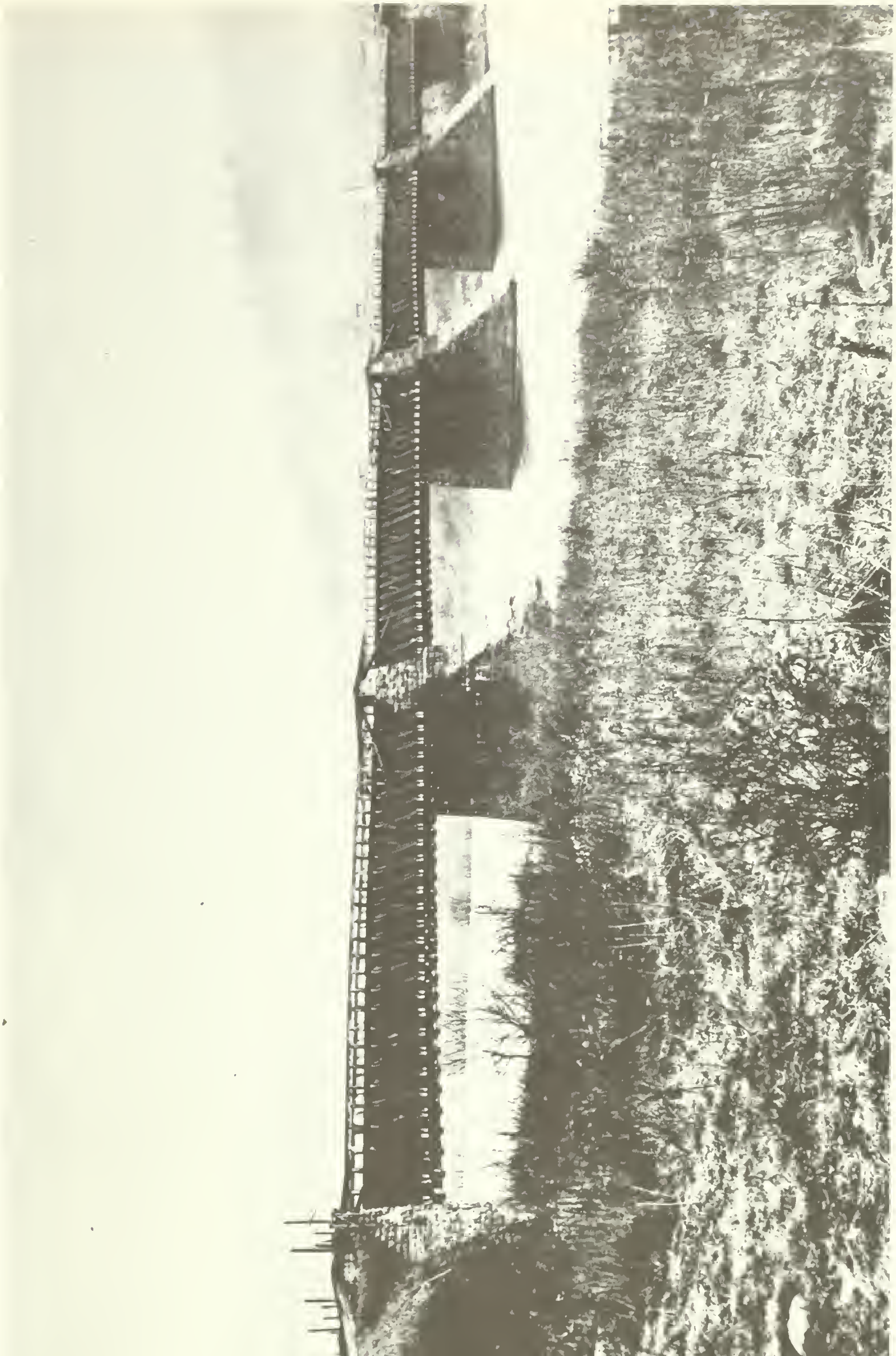
PHOTOGRAPHS

1. Delaware Aqueduct, 1890, looking toward Lackawaxen from Minisink Ford with canal stables and sheds in foreground. Photograph taken from post card, Danny Stango Collection.

DELAWARE & HUDSON CANAL AQUEDUCT, LACKAWAXEN, PA 1890

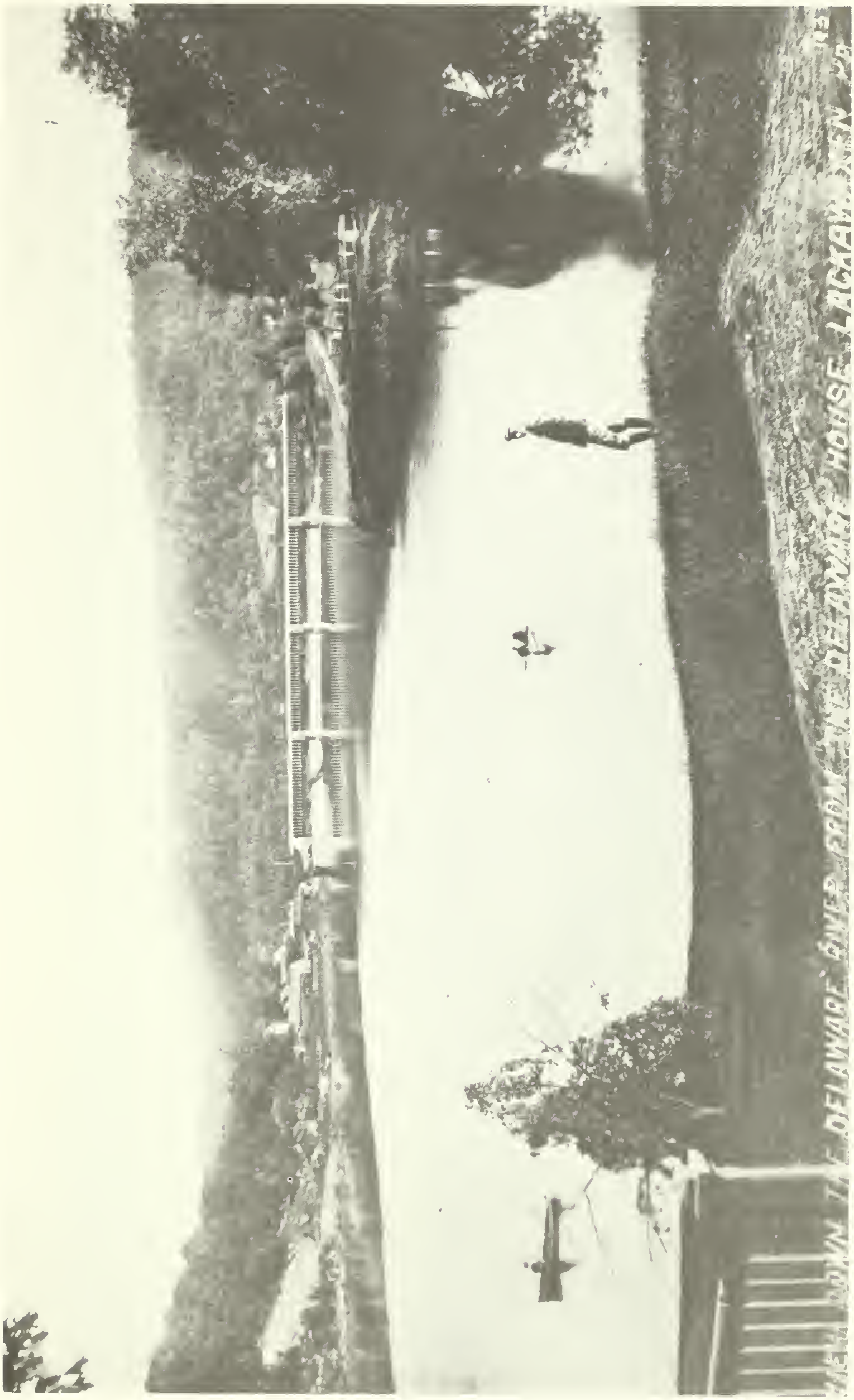


2. Delaware Aqueduct, ca. 1890s, showing upstream side from Minisink Ford. Wakefield Collection, Delaware and Hudson Canal Historical Society.



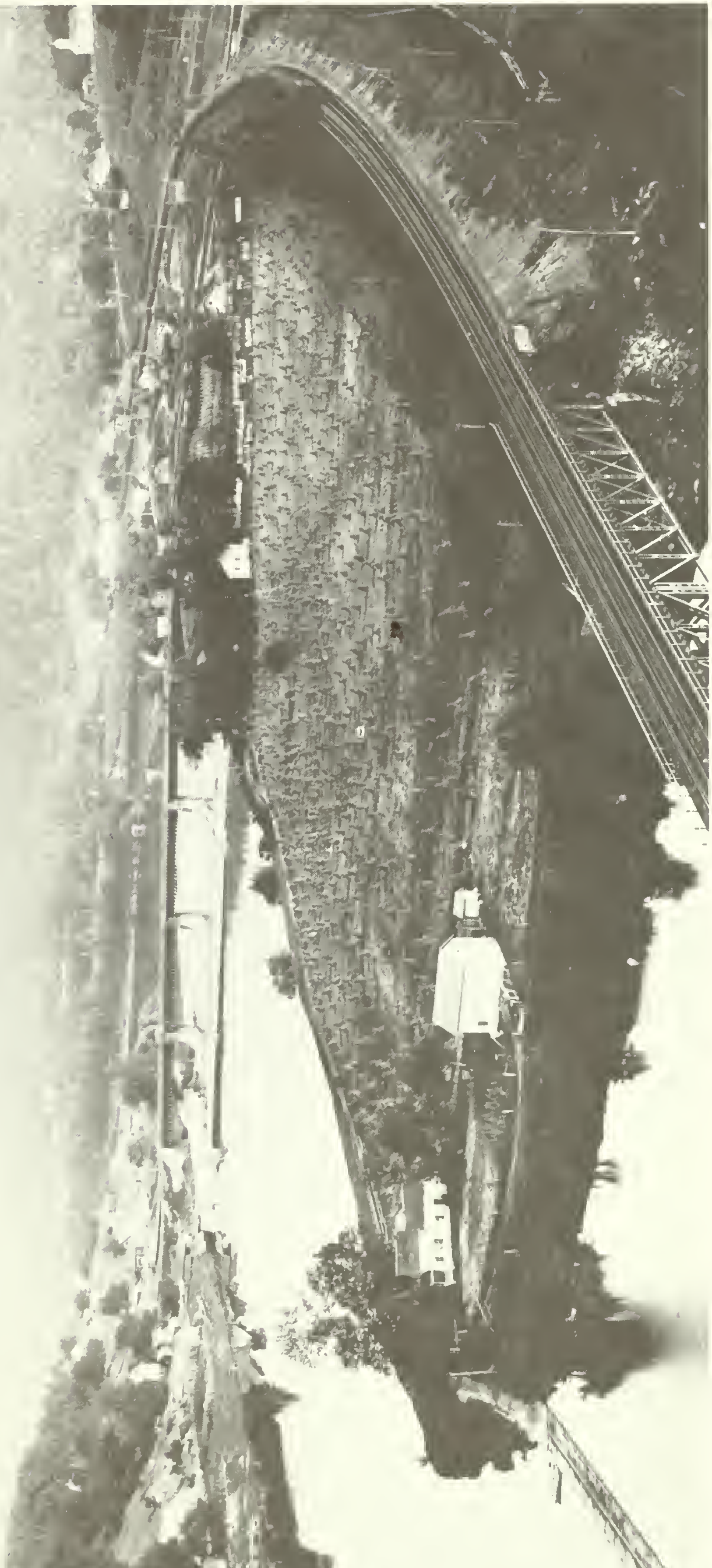
3. Delaware Aqueduct, ca. 1890s, looking upstream from Minisink Ford, Danny Stango Collection.

4. Delaware Aqueduct, ca. 1890s, looking downstream from above the mouth of the Lackawaxen River and showing canal feeder dam in front of aqueduct. Delaware and Hudson Railway Company Collection, New York State Library.

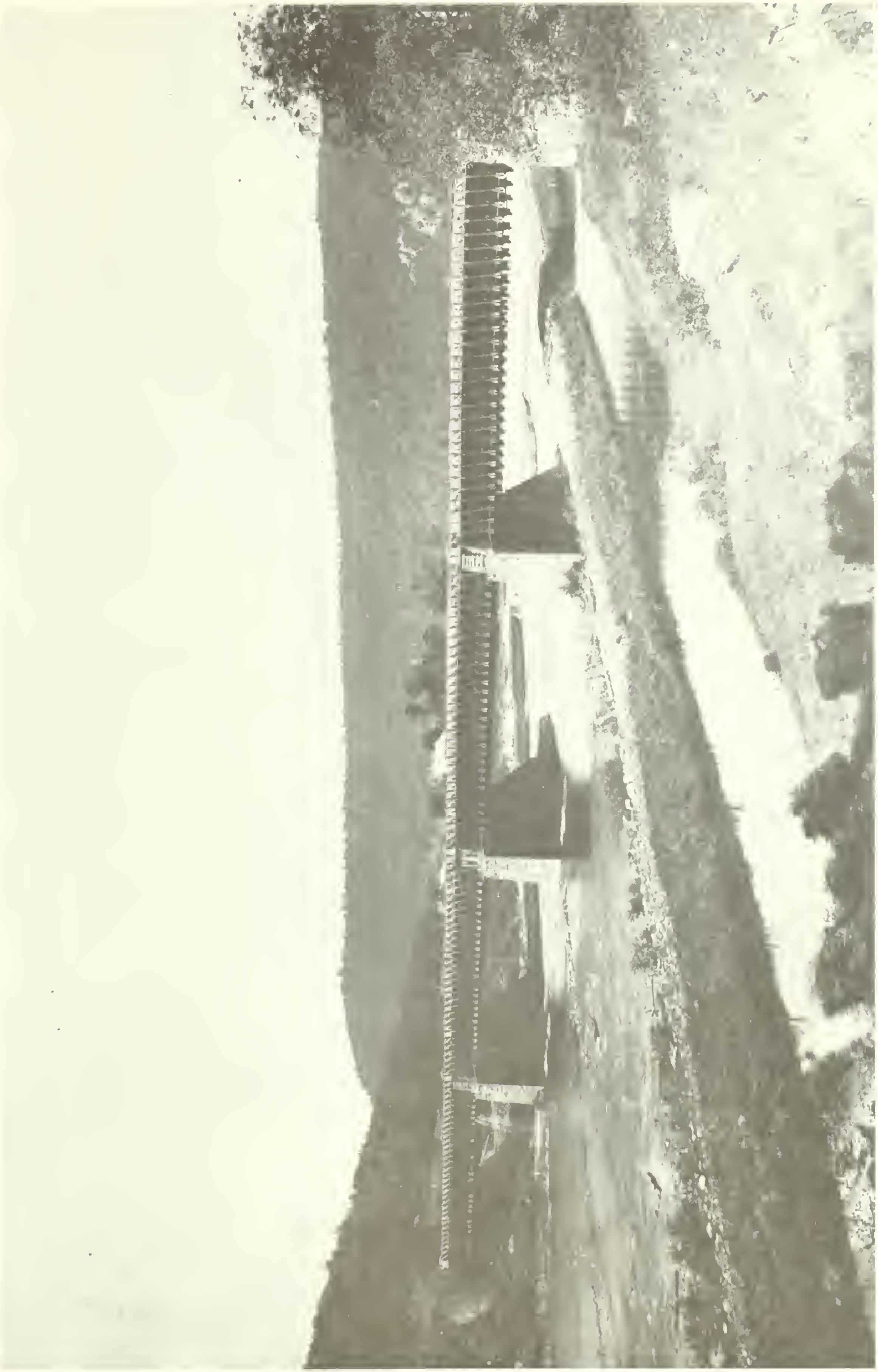


5. Delaware Aqueduct, ca. 1890s, looking upstream and showing canal in foreground. Delaware and Hudson Canal Historical Society.

6. Delaware Aqueduct, ca. 1890s, looking downstream from the mouth of the Lackawaxen River. Wakefield Collection, Delaware and Hudson Canal Historical Society.

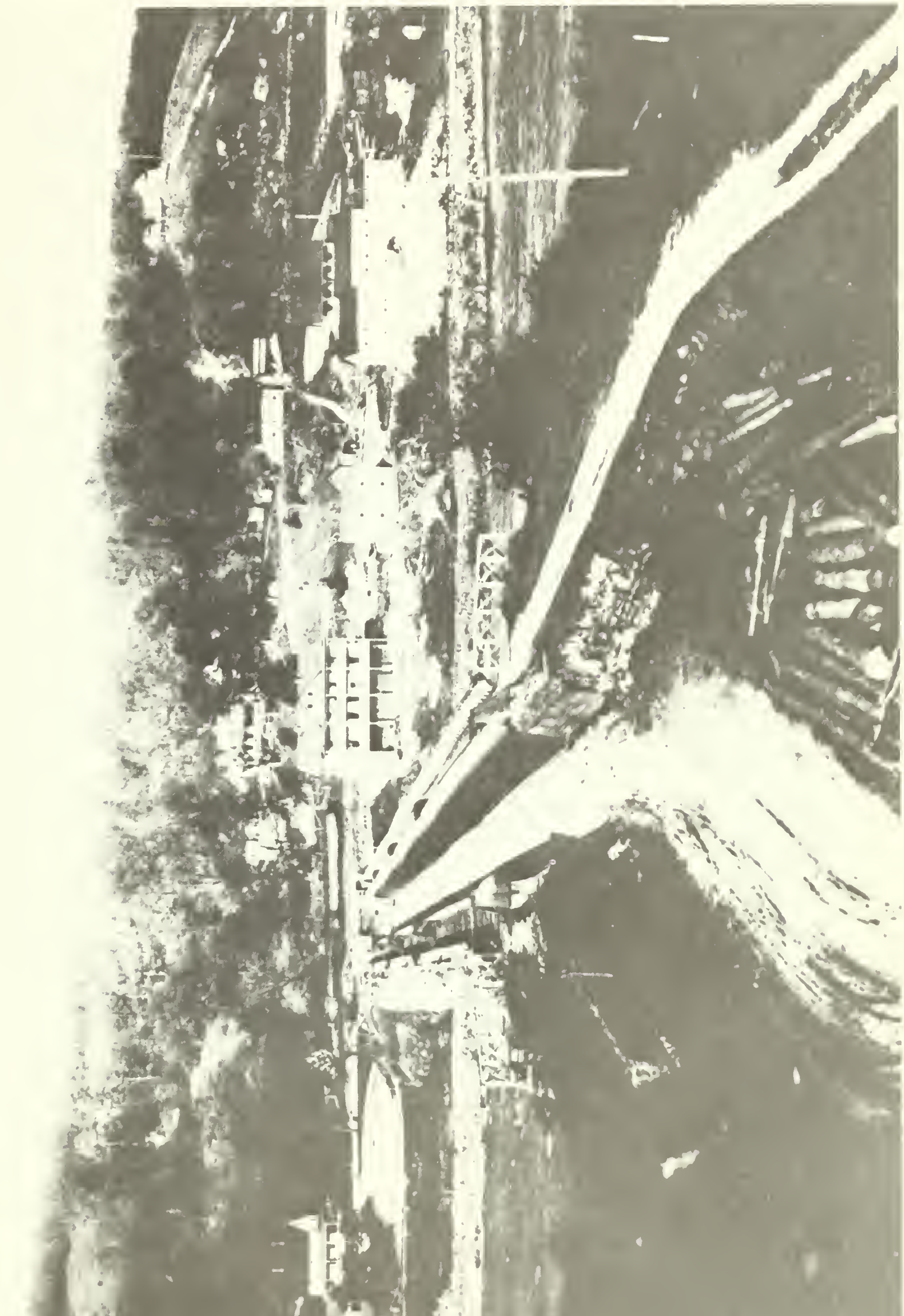


7. Delaware Aqueduct, ca. 1895, looking upstream and showing canal in foreground. Wakefield Collection, Delaware and Hudson Canal Historical Society.



8. Delaware Aqueduct, ca. 1910, looking toward Minisink Ford from Lackawaxen and showing upstream side of aqueduct. Delaware and Hudson Railway Company Collection, New York State Library.

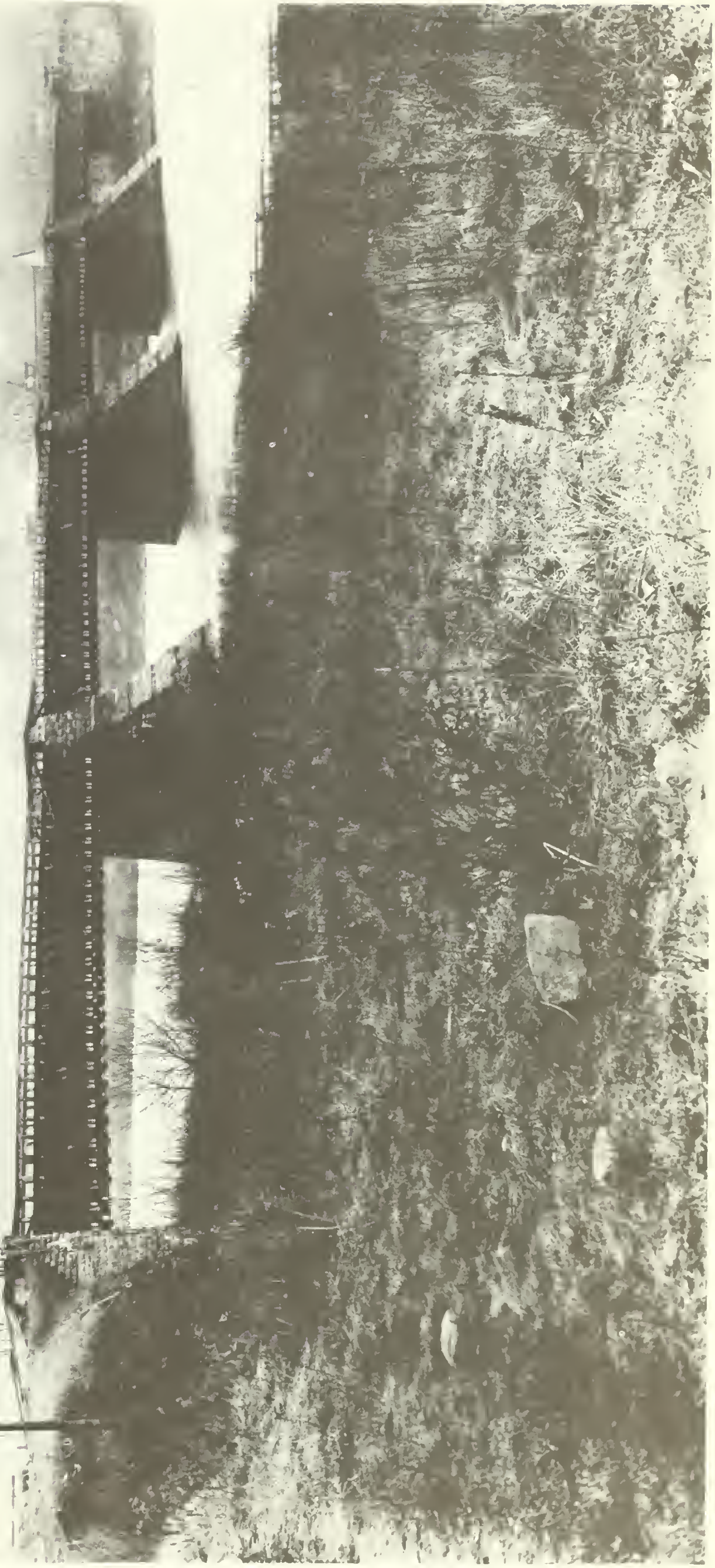
9. Delaware Aqueduct, ca. 1910, looking toward Minisink Ford from Lackawaxen and showing aqueduct while work is underway to make it accessible for vehicular access. Delaware and Hudson Railway Company Collection, New York State Library.



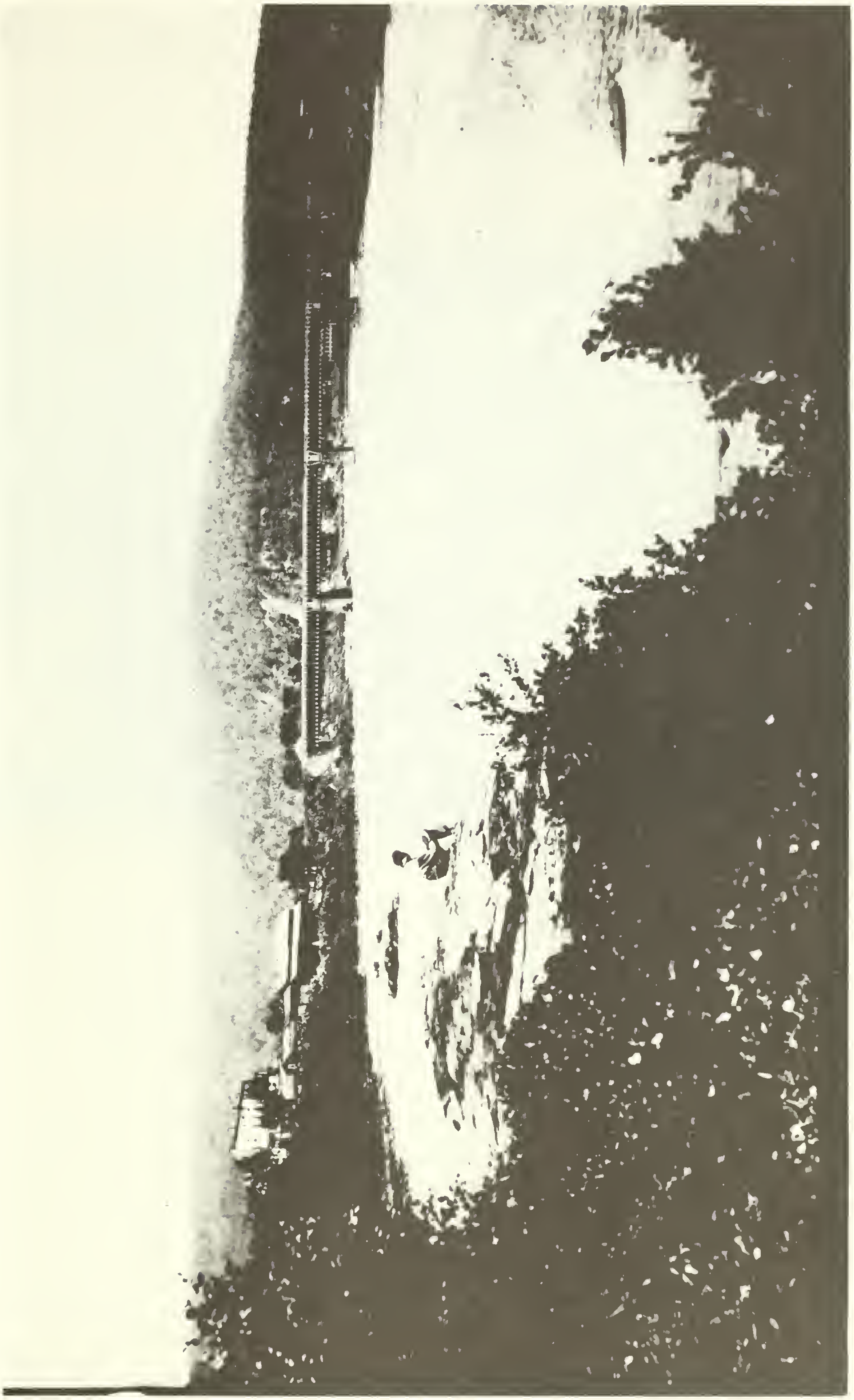
10. Delaware Aqueduct, ca. 1910, looking toward Minisink Ford and showing interior of aqueduct, toll gate, and toll house. Delaware and Hudson Railway Company Collection, New York State Library.

11. Delaware Aqueduct, December 4, 1923, looking toward Lackawaxen and showing toll house. Delaware and Hudson Railway Company Collection, New York State Library.

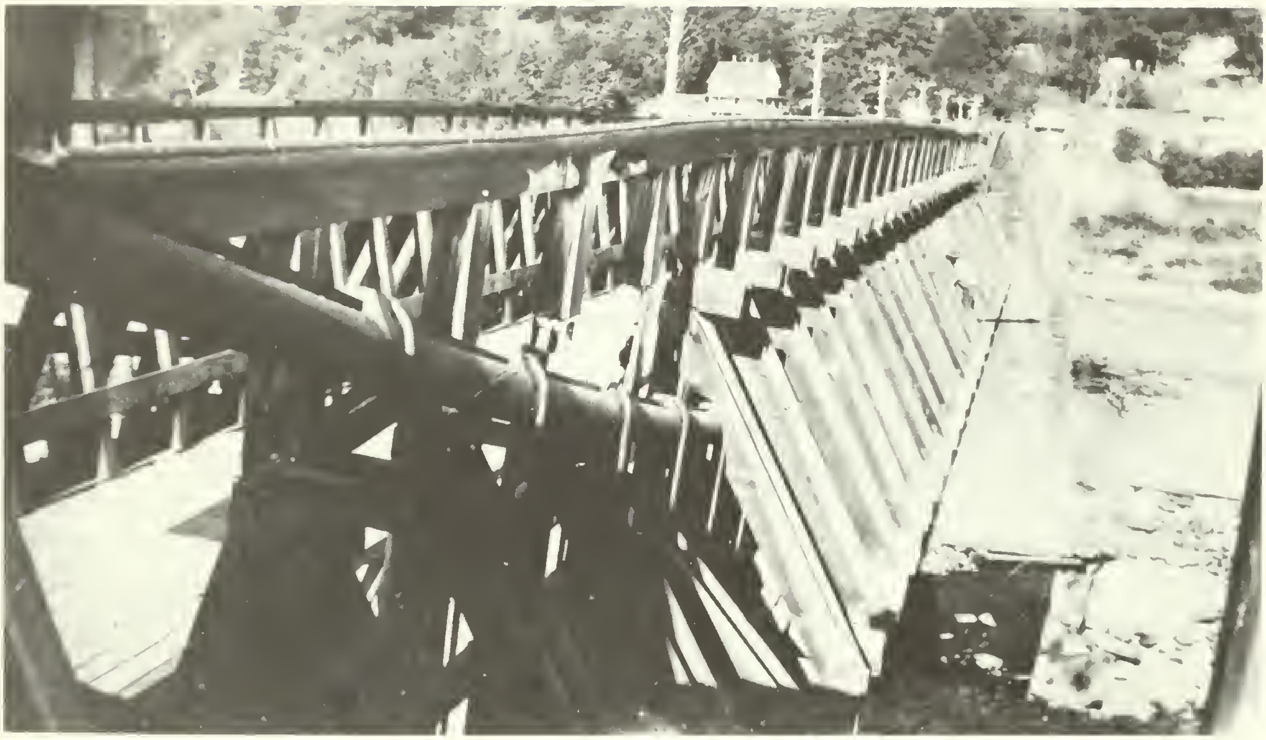
12. Delaware Aqueduct, December 4, 1923, looking toward Lackawaxen from Minisink Ford and showing upstream side of aqueduct. Delaware and Hudson Railway Company Collection, New York State Library.



13. Delaware Aqueduct, May 1, 1924, looking upstream. Delaware and Hudson Railway Company Collection, New York State Library.



14. Modernization of Delaware Aqueduct for highway traffic, 1930-31. Photograph taken by Arthur H. Haupt, Arthur H. Haupt Collection.



15. Modernization of Delaware Aqueduct for highway traffic, 1930-31. Photograph taken by Arthur H. Haupt, Arthur H. Haupt Collection.

16. Modernization of Delaware Aqueduct for highway traffic, 1930-31. Photograph taken by Arthur H. Haupt, Arthur H. Haupt Collection.

17. Modernization of Delaware Aqueduct for highway traffic, 1930-31. Photograph taken by Arthur H. Haupt, Arthur H. Haupt Collection.

18. Modernization of Delaware Aqueduct for highway traffic, 1930-31. Photograph taken by Arthur H. Haupt, Arthur H. Haupt Collection.

19. Modernization of Delaware Aqueduct for highway traffic, 1930-31. Photograph taken by Arthur H. Haupt, Arthur H. Haupt Collection.

20. Modernization of Delaware Aqueduct for highway traffic, 1930-31. Photograph taken by Arthur H. Haupt, Arthur H. Haupt Collection.

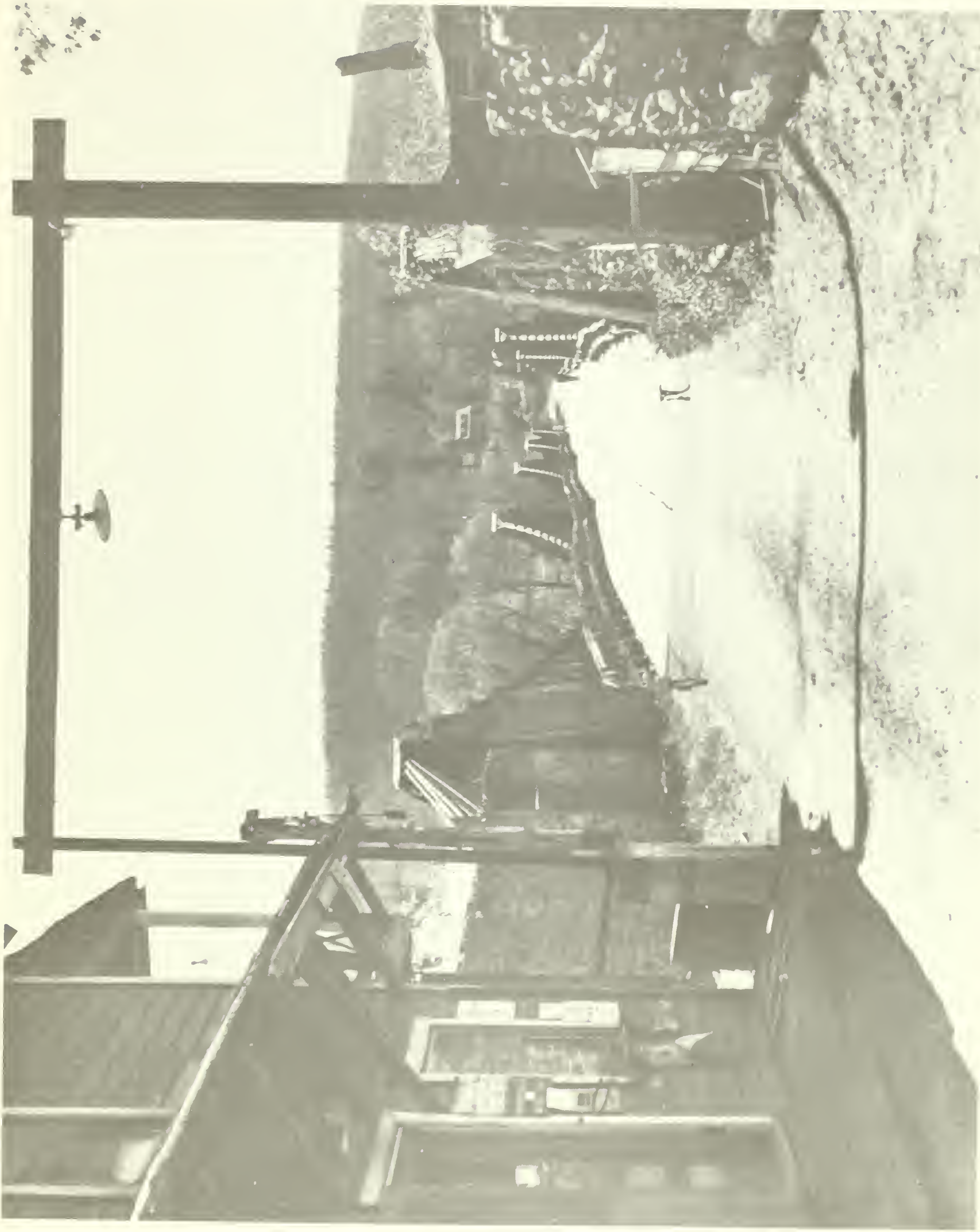
21. Delaware Aqueduct Fire, May 30, 1933. Photograph taken by Arthur H. Haupt, Arthur H. Haupt Collection.

22. Delaware Aqueduct Fire, May 30, 1933. Photograph taken by Arthur H. Haupt, Arthur H. Haupt Collection.

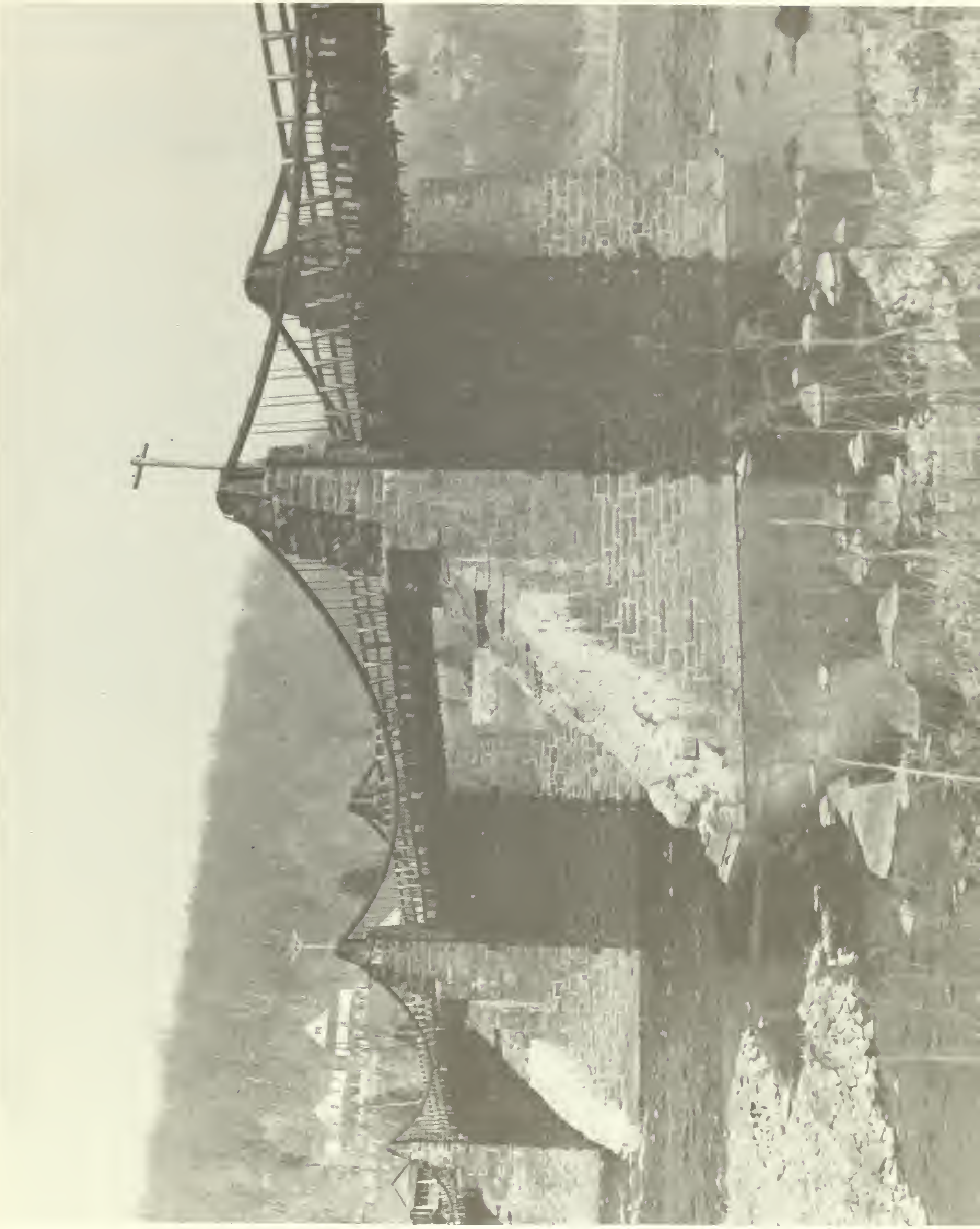
23. Delaware Aqueduct Fire, May 30, 1933. Photograph taken by Arthur H. Haupt, Arthur H. Haupt Collection

24. Delaware Aqueduct Fire, May 30, 1933. Photograph taken by Arthur H. Haupt, Arthur H. Haupt Collection.

25. Delaware Aqueduct toll house and toll gate, April 1968, looking toward Lackawaxen from Minisink Ford. Wagenfohr Photo, Stone Ridge, New York, Delaware and Hudson Canal Historical Society.



26. Delaware Aqueduct, ca. 1970, showing upstream side. Photograph by Jim Shaughnessy, Danny Stango Collection.



Form No 10 306 (Rev 10-74)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM
FOR FEDERAL PROPERTIES

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

SEE INSTRUCTIONS IN *HOW TO COMPLETE NATIONAL REGISTER FORMS*
TYPE ALL ENTRIES -- COMPLETE APPLICABLE SECTIONS

1 NAME

HISTORIC Delaware Aqueduct

AND/OR COMMON
Roebling Bridge, Roebling's Delaware Aqueduct, etc.

2 LOCATION

STREET & NUMBER Upper Delaware National Scenic and Recreational River (located over Delaware River between Lackawaxen, Pennsylvania, and Minisink Ford, New York

__NOT FOR PUBLICATION

CITY, TOWN __ VICINITY OF

CONGRESSIONAL DISTRICT Pa.-10/N.Y.-27

STATE Pennsylvania-New York CODE 42/36 COUNTY Pike, PA/Sullivan, NY CODE 103/105

3 CLASSIFICATION

CATEGORY	OWNERSHIP	STATUS	PRESENT USE	
__DISTRICT	X PUBLIC	__OCCUPIED	__AGRICULTURE	__MUSEUM
__BUILDING(S)	__PRIVATE	__UNOCCUPIED	__COMMERCIAL	X PARK
X STRUCTURE	__BOTH	X WORK IN PROGRESS	__EDUCATIONAL	__PRIVATE RESIDENCE
__SITE	**PUBLIC ACQUISITION**	**ACCESSIBLE**	__ENTERTAINMENT	__RELIGIOUS
__OBJECT	__IN PROCESS	__YES: RESTRICTED	__GOVERNMENT	__SCIENTIFIC
	__BEING CONSIDERED	X YES: UNRESTRICTED	__INDUSTRIAL	__TRANSPORTATION
		__NO	__MILITARY	__OTHER

4 AGENCY

REGIONAL HEADQUARTERS *(If applicable)*
National Park Service (Mid-Atlantic Regional Office)

STREET & NUMBER
143 South Third Street

CITY, TOWN
Philadelphia __ VICINITY OF

STATE
Pennsylvania

5 LOCATION OF LEGAL DESCRIPTION

COURTHOUSE, REGISTRY OF DEEDS, ETC. Pike County Courthouse, Milford, Pennsylvania
Sullivan County Government Center, Monticello, New York

STREET & NUMBER

CITY, TOWN

STATE

6 REPRESENTATION IN EXISTING SURVEYS

TITLE National Survey of Historic Sites and Buildings, Special Report, Delaware and Hudson Canal

DATE
August 5, 1968

X FEDERAL __STATE __COUNTY __LOCAL

DEPOSITORY FOR SURVEY RECORDS National Park Service, National Historic Landmarks

CITY, TOWN
Washington, D. C.

STATE

6. Representation in existing surveys

   b. Historic American Engineering Record - Delaware Aqueduct, Delaware and Hudson Canal

      June-September 1969

      National Park Service, Historic American Engineering Record

DESCRIPTION

CONDITION		CHECK ONE	CHECK ONE
EXCELLENT	DETERIORATED	UNALTERED	X ORIGINAL SITE
X GOOD	RUINS	X ALTERED	MOVED DATE
FAIR	UNEXPOSED		

DESCRIBE THE PRESENT AND ORIGINAL (IF KNOWN) PHYSICAL APPEARANCE

As built in 1847-49, the four-span Delaware Aqueduct carried the Delaware and Hudson Canal over the Delaware River in a wooden trunk suspended by two wire cables designed and erected by John A. Roebling. The cables rested in cast iron saddles placed on the top of small white quartz stone towers having a base of 4 ft. by 6 ft. and rising 4 ft. above the wooden towpaths located on both sides of the trunk. The masonry of the abutments and the three piers, which supported the towers, were composed of gray wacke laid in hydraulic cement.

The cables (each having a diameter of 8-1/2 in. and consisting of 2,150 wires) were each made in one length across the river from abutment to abutment, connected at their ends with wrought iron anchor chains. The lower end of each chain was secured to a heavy cast iron anchor plate of 6 ft. square on which rested a vast amount of masonry whose weight resisted the strain of the chain and cable. The cables were protected against oxidation by paint and varnish and closely encased by a tight wire wrapping.

The Delaware and Hudson Canal was abandoned in 1898 and some ten years later the Delaware Aqueduct was converted into a highway bridge. The canal towpaths were sawn off, a low railing was run alongside the downstream side of the trunk floor to provide a separated pedestrian walk, a toll house was built at the New York end, and some grading was done at each end for accommodation to the existing roads.

In 1930-31 virtually all of the original timber--canal trunk, floor beams, etc.--was removed to permit the reconstruction of the floor system for modern highway traffic. The simple floor system of today was substituted, consisting of transverse floor beams hung from suspenders, longitudinal stringers, and plain transverse plank decking. After a fire destroyed the new woodwork of the Pennsylvania span and part of the one adjacent on May 30, 1933, the floor system was restored quickly and the bridge reopened.

Except for some deterioration the aqueduct's cable suspension system is in generally good condition today. The wooden floor system, which has been renewed periodically since 1930-31, has been deemed unsafe for vehicular traffic and thus the bridge is only open to pedestrian traffic at present.

8 SIGNIFICANCE

PERIOD	AREAS OF SIGNIFICANCE -- CHECK AND JUSTIFY BELOW			
PREHISTORIC	ARCHEOLOGY-PREHISTORIC	COMMUNITY PLANNING	LANDSCAPE ARCHITECTURE	RELIGION
1400-1499	ARCHEOLOGY-HISTORIC	CONSERVATION	LAW	SCIENCE
1500-1599	AGRICULTURE	ECONOMICS	LITERATURE	SCULPTURE
1600-1699	X ARCHITECTURE	EDUCATION	MILITARY	SOCIAL/HUMANITARIAN
1700-1799	ART	X ENGINEERING	MUSIC	THEATER
X 1800-1899	COMMERCE	EXPLORATION/SETTLEMENT	PHILOSOPHY	X TRANSPORTATION
-1900-	COMMUNICATIONS	INDUSTRY	POLITICS/GOVERNMENT	OTHER (SPECIFY)
		INVENTION		

SPECIFIC DATES BUILDER/ARCHITECT

STATEMENT OF SIGNIFICANCE

The Delaware Aqueduct, built in 1847-49 to carry the Delaware and Hudson Canal over the Delaware River between Lackawaxen, Pennsylvania, and Minisink Ford, New York, is the earliest extant suspension bridge of John A. Roebling, one of the leading 19th century American civil engineers who is best remembered for his crowning work--the Brooklyn Bridge--built to his design by his son Washington. The aqueduct is the third work of Roebling's, and in all likelihood, it is both the oldest suspension bridge in the United States and perhaps the oldest extant cable suspension bridge in the world that retains its original principal elements. Thus, the structure is one of the nation's most significant engineering treasures. The sole survivor and largest of the four wire cable suspension aqueducts erected by Roebling for the Delaware and Hudson Canal between 1847 and 1850, the Delaware Aqueduct stands today only because of its strategic location. Following the abandonment of the canal in 1898, the structure was converted to a private highway toll bridge.

The national significance of the Delaware Aqueduct has been recognized both for its historical and engineering importance. Along with four other components of the Delaware and Hudson Canal, the Delaware Aqueduct was designated as a National Historic Landmark in 1968 and was thus included on the National Register of Historic Places. In 1972 the American Society of Civil Engineers designated the structure a National Historic Civil Engineering Landmark.

9 MAJOR BIBLIOGRAPHICAL REFERENCES

Robert M. Vogel. Roebling's Delaware and Hudson Canal Aqueducts. Washington, 1971.

10 GEOGRAPHICAL DATA

ACREAGE OF NOMINATED PROPERTY less than 1 acre

UTM REFERENCES (to be supplied later)

A ZONE EASTING NORTHING B ZONE EASTING NORTHING

C D

VERBAL BOUNDARY DESCRIPTION

Description in Warranty Deed, March 27, 1980, Lackawaxen Bridge Company to United States of America, Sullivan County, Deed Book 959, Folio 121, and Pike County Deed Book 714, Folio 283 and Correction Deed, March 16, 1981, Lackawaxen Bridge Company to United States of America, Pike County Deed Book 772, Folio 56.

LIST ALL STATES AND COUNTIES FOR PROPERTIES OVERLAPPING STATE OR COUNTY BOUNDARIES

STATE	CODE	COUNTY	CODE
Pennsylvania	42	Pike	103
New York	36	Sullivan	105

11 FORM PREPARED BY

NAME / TITLE

Harlan D. Unrau, Historian

ORGANIZATION National Park Service, DSC-TNE

DATE June 6, 1983

STREET & NUMBER 755 Parfet St., P.O. Box 25287

TELEPHONE 303-234-5545

CITY OR TOWN Denver, CO 80225

STATE

12 CERTIFICATION OF NOMINATION

STATE HISTORIC PRESERVATION OFFICER RECOMMENDATION

YES____ NO____ NONE____

STATE HISTORIC PRESERVATION OFFICER SIGNATURE

In compliance with Executive Order 11593, I hereby nominate this property to the National Register, certifying that the State Historic Preservation Officer has been allowed 90 days in which to present the nomination to the State Review Board and to evaluate its significance. The evaluated level of significance is ____National ____State ____Local.

FEDERAL REPRESENTATIVE SIGNATURE

TITLE DATE

FOR NPS USE ONLY

I HEREBY CERTIFY THAT THIS PROPERTY IS INCLUDED IN THE NATIONAL REGISTER

DATE

DIRECTOR, OFFICE OF ARCHEOLOGY AND HISTORIC PRESERVATION

ATTEST DATE

KEEPER OF THE NATIONAL REGISTER

revised 3/81

CLASSIFIED STRUCTURE FIELD INVENTORY REPORT
(Attach 4" x 5" B & W Photo)

REGION Mid-Atlantic PARK/AREA NAME UPDE PARK NUMBER To be supplied by park

STRUCTURE NAME Delaware Aqueduct STRUCTURE NUMBER To be supplied by WASO

LOCATION OF STRUCTURE Highway bridge across Delaware River

NAT'L REGISTER: date: 1968 (mm/dd/yy) MANAGEMENT CATEGORY: (A) (B) (C) (D

NPS LEGAL INTEREST: Fee Simple MGMT AGREEMENT: None (

Check all of the following categories for which NPS has treatment responsibility:

Stabilization(✓) Cyclic maintenance(✓) Routine maintenance(✓) Approved ultimate treatment(✓

APPROVED ULTIMATE TREATMENT: Ultimate treatment presently under discussion - estimated cost of full restoration of $1,000,000

Preservation	(PP)	Restoration	(RR)	Reconstruction	(CC)
Adaptive Preservation	(AP)	Adaptive Restoration	(AR)	Adaptive Reconstruction	(AC)
Neglect	(NG)	Remove	(RM)	No Approved Treatment	(NO)

Approval document: ( ) Document date: (mm/dd/yy)

Estimated Treatment Costs:

			Level of Estimate:	Estimator:
Stabilization:	$	date:		
Approved Treatment:	$	date: (mm/dd/yy)	(A) (B) (C)	(Region)(DSC)(A&E) (

DESCRIPTION:

) Period of Construction: 1847-49 Type of Structure: Bridge (

) Composition: Wire cable suspension bridge-wood deck system Current Interior Use: -- (

Verbal description: The Delaware Aqueduct was constructed by John A. Roebling in 1847-49 as a wire cable suspension structure to carry the Delaware and Hudson Canal over the Delaware River between Lackawaxen, Pennsylvania, and Minisink Ford, New York. The canal was abandoned in 1898 and some ten years later the aqueduct was converted into a highway bridge. In 1930-31 the aqueduct's original woodwork was removed and the simple floor system of today substituted, consisting of transverse floor beams hung from suspenders, longitudinal stringers, and plain transverse plank decking. The toll house at the New York end of the bridge was built ca. 1908. Except for some deterioration the aqueduct's cable suspension system is in generally good condition while the wooden floor system is considered safe only for pedestrian traffic at present.

continue on additional page(s) if necessary

If structure has been removed, how ? -- ( ) date: -- (mm/dd/yy)

Report prepared by: Harlan D. Unrau date: June 6, 1983

As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities to protect and conserve our land and water, energy and minerals, fish and wildlife, parks and recreation areas, and to ensure the wise use of all these resources. The Department also has major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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